NAVAL POSTGRADUATE SCHOOL
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THESIS

AN EXPERIMENT IN
THE VALUE OF INFORMATION CORRELATED TO
THE WAY THE INFORMATION IS PRESENTED

by

Joel Edward Peterson

March, 1985

Thesis Advisor: F.R. Richards

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This thesis investigates the quality of decisions made as a function of the method of representing information and the amount of information presented. A software-controlled sequential decision experiment was conducted. A variation of the game of chess was used as a low-level surrogate for battlefield scenarios. The object was to determine if the amount and method of representing information significantly affected the quality of the decisions made.

The analysis of the collected data indicates that several factors affected the measure of effectiveness. The situation or scenario, the experience of the subject, the way information is represented, and the amount of information all affect the quality of decisions made. Multicolored displays of information helped novice decision makers perform better than experienced decision makers.

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An Experiment in the Value of Information Correlated to the way the Information is Presented

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I. INTRODUCTION

A. BACKGROUND

One of the most important elements of Command, Control, and Communications (C^3) is information handling. Command and control can better be exercised when the essential information is provided to the end user, the decision maker, in the form needed and the decisions made can be effectively disseminated in a quickly comprehensible form and in a timely manner. In a dynamic battlefield environment, attack warning and assessment must be timely and they must be provided in a form which facilitates quick understanding. The information must be sufficient and brief. The feedback, in the form of decisions made, must be received by the tasked forces in a quickly understood form with minimum delay.

Very little investigation has been conducted to determine the efficacy of methods of representing information. Very few studies have looked at the effect of different amounts of information on the quality of decisions made. Therefore, aside from the use of automation, our command information and briefing centers have hardly changed over the years. Today, for the most part, we just have bigger, automated, displays with which to present more information in traditional forms. Computers have allowed us

to increase the amount and speed of display. With the vast amounts of information available today, and the emphasis on timely, qualitative decision making in crisis environments, it is imperative that we find efficient and effective ways to represent information and to determine the essential amount of information needed to make quality decisions.

Commanders know what information they want to make quality decisions. Current strategic and tactical battlefield commanders can have information concerning their area of operations in near real-time. The modern command information centers and briefing rooms have large screens and desktop computer terminals and monitors to display the information requested by the commander. The senior commander wants and gets information in the form with which he or she is most comfortable. The information necessary for a quality decision may be present on a display, but the representation of the information may not enable a quality decision in a timely manner. And, the amount of information presented may be more than is necessary to make a quality decision. To have the right amount of information, in the right form, and at the right time in a dynamic battlefield environment can mean the difference between an effective and an ineffectual decision maker.

B. RELATED STUDIES

Miller [Ref. 1] investigated the channel capacity for absolute judgement and immediate memory of observers. Channel capacity, as it is used here, means the maximum amount of information a person can comprehend, remember, and employ when tested. Miller's study purports a channel capacity increase as more variables or dimensions are added to a display. The study proposes a channel capacity of seven items, give or take two items for one-dimensional stimuli. By recoding information with mnemonic aids, association, and such, the total amount of information a person can deal with can be increased.

Streufert and Streufert [Ref. 2] studied risk taking in decision making as it relates to an amount of information in a given time. In their experiment, civilian decision makers acted as commanders in a simulated invasion of a mythical island. Their experiment showed that the commanders took more risks and made aggressive offensive action decisions when increased time was spent in decision making. The study also substantiated earlier findings that an optimal load of information is attained when ten to twelve independent items of information are received each half-hour. At this rate of presentation of information, the greatest risk taking was observed.

Hayes [Ref. 3], using simulated military problems, researched the data processing limits of Navy enlisted

decision makers. He presented information in alphanumeric matrices. Hayes measured both decision quality and decision time. He found that more than four individual pieces of information decreased the efficiency of decision making. In particular, he observed that unlimited decision time did not increase decision quality when increased information was provided. With a limited time for decision making, the quality of decisions decreased as the amount of information presented increased.

Vincino and Ringel [Ref. 4] evaluated the efficacy of graphic versus alphanumeric information displays. They used black and white transparencies to present battlefield situations to subjects who had a low level of military experience and sophistication. Although they timed their subjects, they allowed their subjects to study each initial situation display until the subject indicated a readiness to continue. The subjects were then shown a second slide depicting one or more battlefield changes in each sector. Their conclusion was that there was no apparent difference in quality of decisions made, speed with which decisions were made, or the confidence of the decisions made between the graphic and alphanumeric presentations.

C. EXPERIMENT FOUNDATION

An experiment conducted by O'Bryant and Risney [Ref. 5] formed the foundation for this thesis. This thesis effort

used a slightly modified reproduction of the O'Bryant and Risney experiment to investigate the effect of different representations of information and amounts of information on decisions made.

Several surrogates for combat have been developed and used to teach, study, evaluate, test, and practice sequential conflict strategy. A computerized, controllable, reputable war game simulates battlefield conflicts. It facilitates data gathering. And, it enables repetitive presentation of different representations of the same information.

O'Bryant and Risney conducted an investigation into the value of intelligence using simulated battlefield scenarios. They used a computerized variation of chess with alphanumeric displays as their war gaming model. Chess requires sequential decision making and is the oldest known war game in western civilization. The Joint Chiefs of Staff (JCS) Joint War Gaming Manual classifies chess as a research type war game [Ref. 6].

In their experiment, the chessboard was duplicated through the use of a cathode ray tube (CRT) display and a computer. Their subjects, mid-level United States (US) military officers, each played four war games. In each surrogate war, the subjects were presented a different battlefield situation and a different level (amount) of information. The levels of information pertained to

friendly and enemy force positions, dispositions, strengths, and vulnerabilities. The objective was to depict simulated battlefield situations and evaluate the quality of decisions made as related to the level of information presented. The measure of effectiveness (MOE) or measure of decision quality was a game score. The score was based on the remaining available forces for both sides at the conclusions of simulated conflicts. The score was a quantitative measure of which side had the advantage and the magnitude of the advantage. O'Bryant and Risney attempted to show that the decision maker's effectiveness (game score) was not a monotone function of the amount of information presented. Instead, they believed that: given a particular method of presenting information, the relationship between effectiveness and quantity of information was monotone increasing up to a certain information level, beyond which effectiveness would decrease indicating a condition of information overload. Their experiment confirmed this hypothesis of the existence of information overload by showing that decision makers in a chess game were significantly more effective in some scenarios with less information.

The information level which most closely resembled the normal view of the chessboard was the best experimental information level among four levels of information presented. They thought they could attribute this to the

idea that the information was in a form most familiar to the end users. When they presented the display containing the greatest amount of information, they felt the amount of information could not be effectively used. Two reasons for the subjects having failed to use the information were proposed; 1) the method of representing the information did not facilitate quick comprehension of the information provided, or 2) there simply could have been too much information to digest and use in the allotted time. They reasoned that there is some quantity of information that is optimal for each method of representation. They considered that there exists some amount of data that is excessive regardless of the method of representing the information. One area this study investigates is the possibility that representing the same information levels in a graphic form would remove the affect of the information overload found in their experiment.

D. SCOPE

This is a study to determine if the way information is displayed and the amount of information presented adds to or detracts from a person's ability to make quality decisions. To study the effect of different representations of information on decisions made, this study used graphic displays in place of the alphanumeric displays used in the O'Bryant and Risney experiment. The graphic displays

represented information with iconic chess symbols. The graphic display experiment was conducted in two phases. One phase used color surrogate battlefield displays and the other phase used monochrome-green surrogate battlefield displays.

This study investigated the effect of three representations of information on the quality of decisions made. One objective of the study was to determine if one of the following three ways of representing information best facilitates quality decision making: alphanumeric display, color graphic display, or monochrome-green graphic display. The study also looked at the effect of four different amounts of information on the quality of decisions made. The objective here was to determine if there was such a thing as too much information. Too much information, based on information overload theory, results in a decrease in the quality of the decision(s) made. The score for each game, the measure of the quality of decisions made, was the MOE for this experiment. The scores were derived the same way in this experiment as they were in the O'Bryant and Risney experiment.

Except for the ways of representing information and interacting with displays, the experiments were replicates. As a result of the graphic experiment design, the subjects used a mouse and tablet to record and disseminate their decisions. The subjects in the O'Bryant and Risney

experiment had used a keyboard to interface with their displays.

With the game of chess, each piece can be considered as a maneuver element with certain detection and engagement capabilities. It may help to envision this concept if you think of each piece as having radar coverage and field of fire commensurate with its maneuver capability. The game of chess has force attrition due to engagements and enables limited resupply. Limited resupply is accomplished when a Pawn reaches the chessboard back row (resupply point) of the opposing force and an exchange is made for a much more highly maneuverable and sophisticated combat unit.

At the beginning of each chess game, the subjects were told that force numbers and strengths were fairly equal for both sides of the board. The four levels of information always displayed all of the friendly forces. Two of the levels displayed some of the enemy forces and two of the levels displayed all of the enemy forces. Three of the levels identified enemy forces which were susceptible to capture. And, two of the levels identified safe areas for friendly forces. The alphanumeric displays depicted friendly forces with the preceding character of W, for White, and the enemy forces with the preceding character of B, for Black. The color graphics displayed blue iconic figures for friendly forces and red iconic figures for enemy forces. For the monochrome-green graphics displays, there

was no shade differentiation between the friendly and enemy iconic figures. Therefore, after receiving an initial "report" on which forces were friendly and which were enemy, the subjects in the monochrome-green phase had to mentally keep track of their own forces.

Level 1, the lowest level of information, presented the friendly chess pieces, and only those enemy chess pieces which could be captured by the friendly pieces on the subject's current move. This level of information represents the battlefield when the commander first skirmishes with the enemy. Intelligence reports indicated that the opposing forces, all or several of which were not visible, were comparable in strength. Now, the commander receives reports of actual enemy contact from reconnaissance patrols. The commander can engage only one enemy element at a time, withdraw, or maneuver his or her forces to protect and add depth to one of the friendly leading elements. This is a precarious situation because an unseen enemy may be poised for a strike against friendly forces or as reserve to an endangered enemy element. This scenario simulates fighting in a guerrilla war.

Level 2 presented all the friendly pieces, those enemy pieces which could be captured, and safe areas. Again, intelligence reports indicated the opposing forces were comparable in numbers and strength, and all, or a sizable portion of the enemy force, would not be visible. Safe

areas are positions safe from enemy attack. In the graphics experiment, safe areas were identified by means of a little box in the lower left corner of an appropriate chessboard square. A safe square could be an unoccupied square or a square currently occupied by a friendly or enemy piece. The annotation of a safe square meant a friendly piece on that square would be safe from attack by an enemy piece on the enemy's next move. This type of scenario represents a battlefield situation where there are limited intelligence reports along with forward element contact reports. In this case, intelligence reports the enemy elements which can not be supported if attacked, the friendly elements which are free from attack, and safe areas for friendly forces if they could move into those positions. Because the decision maker knew which of his or her forces were in jeopardy, the quality of the decision made under these conditions was better than decisions made under the conditions of least information.

Level 3 provided the normal view of the chessboard. This amount of information was found to be best for the alphanumeric experiment and for the color phase of the graphic experiment. This level can be equated to complete knowledge of enemy elements and numbers in the the battlefield area, but having no indication of probable enemy intentions. Except for the decision maker's own understanding of and experience with similar conflict

situations, the only information available to the subject was the raw data on friendly and enemy force element locations. This level most relies on the decision maker's ability to use raw data, know enemy element capabilities, contemplate enemy intentions, and orchestrate friendly forces in a conflict environment.

Level 4 displayed the most information. This was the best level of information in the monochrome experiment. It resulted in the best scores. The display showed all the pieces, annotated the safe positions as was done with level two, and identified enemy pieces which were susceptible to capture. The vulnerable enemy pieces were identified in the graphics experiment by a little box in the lower right corner of each appropriate chessboard square. This level of information can be equated to multi-sensor intelligence information on the battlefield situation. The enemy's intentions are not actually known, but probable enemy courses of action are made known to the friendly force commander. Based on enemy capabilities, vulnerable, unsupported enemy forces, endangered friendly forces and safe areas are known.

For this experiment, five hypotheses were formulated:

1. There is no difference in performance based on the level of information presented.

2. There is no difference in performance based on the situation or scenario.

3. There is no difference in performance based on the sequence of events, trial order.

4. There is no difference in performance based on the experience of the subject.

5. There is no difference in performance based on how the information is represented.

E. APPROACH

The approach to this investigation followed standard experimentation practices. A problem was identified. The problem is twofold. It is identified as the way information is represented and the amount of information presented to decision makers. The problem was bounded by using a variation of the game of chess as a surrogate for sequential decision making conflict situations, representing "battlefield" displays in more than one way, and providing four levels of information to decision makers.

Chapter II discusses the experiment used as the baseline for this experiment.

In Chapter III, the experiment design, subjects, apparatus and materials, and procedures are discussed.

Chapter IV examines the captured data and explains the tools used for analysis.

The experiment conclusions and recommendations are presented in Chapter V.

II. EXPERIMENT BASELINE

A. OVERVIEW

O'Bryant and Risney [Ref. 5] automated their experiment to facilitate control and data collection. They designed and developed a computer program to control the communication between, and the displays for, a subject and the game umpire. The program also timed each move of a subject, checked for legal moves, and collected and wrote data saves to a file for future analysis. The program was written in FORTRAN 77 and consists of 25 subroutines in three files. The software resides in and runs on a Digital Equipment Corporation (DEC) VAX 11/780 minicomputer system at the Naval Postgraduate School (NPS) Wargaming Analysis and Research Laboratory (WAR Lab). The program uses DEC VAX 11/780 Systems Programming Calls.

Their experiment used thirty-one US military officers as participants. Every subject played four chess surrogate war games. Different opening board (about ten moves into a game) set ups were used for each game to represent different situations. Each game presented a different amount of information.

Their experiment measured the quality of decisions made under various levels of information. At the end of each game, a score (MOE) was derived by a computerized chess

game. With the computerized game, they evaluated the opening board and determined each end-game score. These derived values were based on a composite of the appropriate game board's material and positional strengths. The end-game score for each game was adjusted to reflect the opening game set up and any penalty points accrued by the subject.

Their analysis suggests a relationship between the amount of intelligence provided and a decision-maker's performance. They concluded that there is an information level such that more or less information resulted in a decrease in performance. Their experimental analysis supports the concept of information overload. This experiment investigates the possibility that their information overload was really a factor of the method of presentation.

B. SCENARIOS

O'Bryant and Risney used four scenarios in their experiment. Since successive games could have more or less information than the current game, each game presented a different scenario. The subjects were therefore precluded from memorizing a chessboard set up and using that knowledge to assist in playing a subsequent game which may have presented less information. Figures II-1 through II-4 show the scenarios using alphabetic format. The chess pieces are depicted by two alpha characters. B or W in the first

character position denotes a Black or White piece respectively. The second character uses P for Pawn, B for Bishop, R for Rook, N for Knight, Q for Queen, and K for King. The figures show example chessboard displays from their experiment as they were depicted in alphanumerics on the monitor. For the O'Bryant and Risney experiment, the subjects used standard chess notation and keyboard entry to make their moves.

```
-- BR BB BQ BR ** BK **
** BP BP -- ** BP BB BP
BP ** BN BP BP BN BP **
** -- ** -- ** -- ** --
-- ** WP WP WP ** -- **
** WP WN -- WB WP ** --
WP ** -- WQ WN ** WP WP
** -- WR -- WK WB ** WR
```

Figure II-1
Initial Set Up A

```
BR ** -- ** -- BR BK **
BP BP ** BN BB BP BP --
-- BQ -- ** BB BN -- BP
** -- BP BP ** -- ** --
-- ** -- WP -- ** -- WB
** -- WP WB ** WN ** WP
WP WP -- WN -- WP WP **
WR -- ** WQ WR -- WK --
```

Figure II-2
Initial Set Up B

```
-- ** -- BQ -- BR BK **
** -- BP -- BN BP BB BP
-- ** -- BP -- BN BP **
** BP ** WP BP -- WB --
-- WP -- ** WP ** BB **
** -- BR -- ** WN ** --
-- ** WP WQ WB WP WP WP
** -- ** WR ** WR WK --
```

Figure II-3
Initial Set Up C

```
BR ** BB BK -- BB -- BR
BP -- ** -- ** BP BP BP
-- ** BP ** -- BN -- **
** WN ** -- ** -- ** --
-- ** -- ** -- ** -- **
** -- WN -- ** -- ** --
WP WP -- ** WP WP WP WP
WR -- ** -- WK WB ** WR
```

Figure II-4
Initial Set Up D

C. INFORMATION LEVELS

Four different games with differing information levels were played by each subject. Figure II-5 depicts the information levels used in the experiments in graphic form.

The sequential numbers for the information levels have no real meaning, they are non-quantitative. Level one is for the least amount of information presentation, level two represents the presentation of some information, level three is for the normal view of the chessboard, and level four represents the presentation of the normal view of the chessboard plus some additional information.

```
Information
Level
   ¶-----------------------------------------------------¶
 4 ¶*****************************************************¶
   ¶                                                     ¶
 3 ¶************                           **************¶
   ¶                                                     ¶
 2 ¶****************************************             ¶
   ¶                                                     ¶
 1 ¶**************************                           ¶
   ¶-----------¶-------------¶-------------¶-------------¶
     Friendly    Vulnerable    Safe          Enemy
     Pieces      Enemy         Positions     Pieces
                 Pieces        (Specified)
                 (Specified)

                   Information Displayed
```

Figure II-5
Information Level Versus Information Displayed

D. COLLECTED DATA

Data were automatically collected during the conduct of the experiments [Figure II-6]. The collected data consist of several items of interest. The monitor displays for the first and tenth moves were saved in alphabetic format. The first four lines of the headings for each of these chessboard depictions is the same. The subject's name is

```
PLAYERS NAME IS:  XXXXX
EXPERIENCE LEVEL IS:  B
MOVE # = 1
TYPE OF SCENARIO = 1
INITIAL BOARD SET UP = B

BR ** -- ** -- BR BK **
BP BP ** BN BB BP BP --
-- BQ -- ** BB BN -- BP
** -- BP BP ** -- ** --
-- ** -- WP -- ** -- WB
** -- WP WB ** WN ** WP
WP WP -- WN -- WP WP **
WR -- ** WQ WR -- WK --
W. R/QR1-QN1                TIME = 112.9 SECONDS
B. Q/QN3-QR4
W. Q/Q1-K2                  TIME =  25.4 SECONDS
B. Q/QR4*P/QR7
W. P/KN2-KN3                TIME = 127.5 SECONDS
B. B/K2-Q3
W. Q/K2-Q1                  TIME =  76.0 SECONDS
B. P/QB4*P/Q5
W. N/KB3*P/Q4               TIME =  69.6 SECONDS
B. B/K3*P/KR6
W. Q/Q1-QB2                 TIME =  59.1 SECONDS
B. R/QR1-K1
W. B/Q3-KR7 CHECK           TIME =  41.8 SECONDS
B. N/KB3*B/KR2              EVALUATION CODE =   0589 BL
W. K/KN1-KR2                TIME =  49.9 SECONDS
B. B/KR6-KN5                EVALUATION CODE =   0582 BL
W. P/KB2-KB3                TIME =  34.9 SECONDS
B. B/KN5-K3

PLAYERS NAME IS:  XXXXX
EXPERIENCE LEVEL IS:  B
MOVE # = 10
TYPE OF SCENARIO = 1
INITIAL BOARD SET UP = B
EVALUATION CODE = 0568 BL

-- ** -- ** BR BR BK **
BP BP ** BN ** BP BP BN
-- ** -- BB BB ** -- BP
** -- ** BP ** -- ** --
-- ** -- WN -- ** -- WB
** -- WP -- ** WP WP --
BQ WP WQ WN -- ** -- WK
** WR ** -- WR -- ** --
```

Figure II-6
Example of Captured Data

the first entry (the example uses XXXXX). An experience level with A = never played, B = novice player, C = frequent player, and D = tournament player is the second entry. The move number, 1 or 10, is the next entry. The type of scenario, amount of information, where 1 = normal view, 3 = least amount of information, 5 = some information, and 6 = most amount of information is the fourth entry. The initial board set up of A, B, C, or D is the fifth and last entry in the lead header. The tenth move header includes an evaluation code. All moves were saved. The moves are preceded by a W or B for White or Black moves. An example move is R/QR1-QN1; meaning Rook at Queen's Rook1 moves to Queen's Knight1. The "*" means takes or captures. In addition, the amount of time the player took to make his or her move, and a hexadecimal evaluation code for the eight, ninth, and tenth moves were saved. A BL or WH after the evaluation code stands for Black or White advantage at that point. All the output for the experiments resides in the WAR Lab computer system in the CHESS directory.

E. SUMMARY

This chapter reviewed the experiment used as the baseline for this study. The programs O'Bryant and Risney developed to control their experiment, the subjects they used, their MOE, and their conclusions were discussed and an example of the captured raw data was presented.

III. EXPERIMENT METHODOLOGY

A. INTRODUCTION

This chapter presents the methodology of the graphic display experiment. The methodology includes the design, a description of the subjects, apparatus and materials used, and the procedure for conducting the experiment.

B. EXPERIMENT DESIGN

1. Overview

Because this experiment was a close copy of a prior experiment in the same computer laboratory facility, many of the necessary apparatus, materials, and software were readily available or appropriate with slight modification.

The identified factors which could affect the value of the MOE were alphanumeric versus graphic displays and color versus monochromatic attributes, level of information provided, opening chessboard, game order, and the chess playing experience of each participant. This experiment was a highly structured, carefully controlled evaluation to facilitate formal numerical analysis and replication for further investigation.

The dependent variable for the experiment, the score (MOE), was a quantitative measure reflecting the quality of decisions made. The score was derived by the proprietary

algorithm of the selected computerized challenger. A score was saved after move eight, nine and ten. The scores saved for moves eight and nine were for contingency purposes. The score at the end of move ten was used as the unadjusted game score. Each score was derived from the composite of material and positional board strengths for the remaining chessboard pieces. A positive score indicated the degree to which the subject was ahead and a negative score indicated the degree to which the computerized challenger was ahead. All scores were negative by end-game.

The independent variables included the method used to represent the information--graphical in color or in monochrome-green, or by alphanumeric displays. They include also the ordering in which the information was presented; the experience level of the participants; the scenario or set up; and the amount of information provided. The mathematical model for the experiment is a general linear model.

The experiment was conducted in the NPS WAR Lab with very few outside materials. A DEC VAX 11/780 minicomputer system and typical computer facility equipment consisting of terminals, keyboards, and high resolution graphics display monitors with mouse and tablet interface were used. The outside materials consisted of a Fidelity Electronics, Limited, Super Sensory "9" Chess Challenger, a questionnaire [Appendix D], and a standard chess set.

2. <u>Design</u>

For any experiment, one first identifies a problem, narrows the problem to a workable level, formulates hypotheses and then sets about the task of determining an appropriate way to test the hypotheses.

The mathematical model for the MOE and factors of interest are:

$$Y = \mu + \alpha_i + \beta_j + \gamma_k + \delta_l + \rho_m + \epsilon$$

where:

Y = MOE

μ = mean of population, common effect in observations

α_i = information level effect (i= 1, 2, 3, or 4)

β_j = scenario effect (j= 1, 2, 3, or 4)

γ_k = trial number effect (k= 1, 2, 3, or 4)

δ_l = experience level effect (l= 1, 2, or 3)

ρ_m = experiment presentation (m= 1-color, 2-monochrome, or 3-alphanumeric)

ϵ = random, unknown or uncontrolled error

A master schedule [Figure III-1] was used to assist in the conduct of the experiment. One master schedule was completed for the color phase, and a separate master schedule was completed for the monochrome phase of the graphic experiment. When a subject participated in the WAR Lab, the master schedules were checked to determine the appropriate phase, color or monochrome, the trial (game),

Experiment Schedule

	Subject	Exp	IS	Score	IS	Score	IS	Score	IS	Score
1.			1A		5B		3C		6D	
2.			5A		1B		3D		6C	
3.			3A		1C		5B		6D	
4.			6A		1C		5D		3B	
5.			1A		5D		6B		3C	
6.			5A		1D		6C		3B	
7.			3B		1A		6C		5D	
8.			6B		1A		3D		5C	
9.			1B		3C		5A		6D	
10.			5B		3C		1D		6A	
11.			3B		5D		1A		6C	
12.			6B		5D		1C		3A	
13.			1C		3A		6B		5D	
14.			5C		3A		6D		1B	
15.			3C		5B		6A		1D	
16.			6C		5B		3D		1A	
17.			1C		6D		5A		3B	
18.			5C		6D		1B		3A	
19.			3D		6A		1B		5C	
20.			6D		3A		1C		5B	
21.			1D		6B		3A		5C	
22.			5D		6B		3C		1A	
23.			3D		6C		5A		1B	
24.			6D		3C		5B		1A	
25.			1A		5B		3C		6D	
26.			1D		5B		3A		6C	

Legend:

Exp = Experience Level (1, 2, 3, or 4)
IS = Information Level Menu Number (1, 3, 5, or 6)
Scenario Character (A, B, C, or D)

Figure III-1
Master Schedule

the information level, and the scenario (initial board set up) to be used. The completed schedule contained the subject's name, experience level, order of amount of information/scenario combinations, and scores. Subjects were randomly matched to a subject number. The only constraint

was that of having an equal number of subjects in each of the two phases.

The master schedule was developed pseudo-randomly. It was based on the desired use of four different information levels and four different scenarios in four trials. Because there were four information levels to present to each subject, that meant there were four items (information levels) taken four at a time (four trials per subject) for twenty-four permutations. A minimum of twenty-four subjects were required to play the different possible lineal orders of the different levels of information in four games. Because there were four different scenarios, this also meant four items (scenarios) taken four at a time (four trials per subject) for twenty-four permutations.

There was no attempt made to compute all the possible lineal orders for four trials of four different information levels and four different scenarios. Random selection of the trial combinations was accomplished by overlaying the scenario permutation schema on the information level permutation schema. This ensured all information level lineal orders were used and that each subject played a different scenario for each of the four trials.

The four levels of information were selected from a menu [Figure III-2] which was displayed on the umpire's game terminal. Information levels 1, 3, 5 and 6 were used for

TO INITIALIZE THIS PROGRAM SELECT THE TYPE
OF BOARD DISPLAY FOR THE PLAYER.

1.-- DISPLAY ENTIRE BOARD
3.-- DISPLAY WHITE PIECES AND BLACK'S PIECES THAT CAN BE ATTACKED
5.-- DISPLAY WHITE PIECES, WHITE SAFE MOVES, AND BLACK PIECES THAT CAN BE ATTACKED
6.-- DISPLAY ENTIRE BOARD, BLACK PIECES THAT CAN BE ATTACKED, AND WHITE SAFE MOVES

Figure III-2
Information Level Selection Menu

the experiment. The numbers were used by the game umpire to provide the displays of the appropriate information level for each game. Selection of number 3 presented the least amount of information, number 5 presented some additional information, number 1 provided more information and number 6 provided the most amount of information to the subject. On the data sheets, [Tables III-1, III-2, and III-3], 1 = least amount of information, 2 = some information, 3 = more information and 4 = most information.

The experiment was designed specifically to simulate tactical military situations. The information levels of the experiment simulated battlefield situations. Consider that each chess piece has certain target acquisition, radar coverage, maneuver, and target engagement, strike, capabilities. For example, some challenger pieces appeared or disappeared as they moved in or out of friendly radar coverage or fields of fire. This was the case with information levels 1 and 2, where the

enemy pieces appeared and disappeared during the game. A similar thing happened in level 4 where annotations identifying vulnerable challenger pieces appeared or disappeared with each move.

Four different initial board set ups were selected [Figures III-3 through III-6]. On the data sheets, 1 = Scenario A, 2 = Scenario B, 3 = Scenario C and 4 = Scenario D.

To simulate timely decision-making, subjects were allowed two minutes per move prior to being assessed a point penalty. For every minute, or fraction of a minute, past the deadline, a penalty was assessed. Each penalty was equal to the material value of one pawn (256 points).This restriction was used to eliminate the possibility of slow play due to fatigue. To assist participants, the time taken for a subject's first move for each game was not subject to penalty. Therefore, the initial chessboard display could be adequately studied.

The opening chessboard presentations were approximately ten moves into a game. By using these set ups, the number of moves required for a subject to confront a challenger or be confronted was greatly reduced.

The MOE score was obtained after the tenth move initiated by the subject (game move twenty). This allowed maneuvering and yet decreased the possibility of checkmate. Every game played to conclusion would have resulted in a

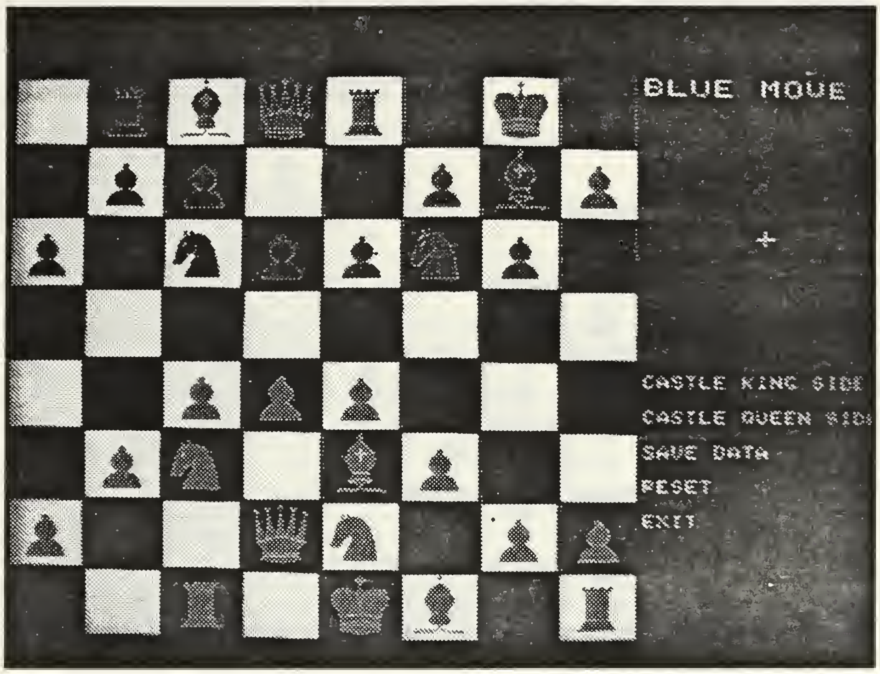


Figure III-3
Initial Graphic Scenario A

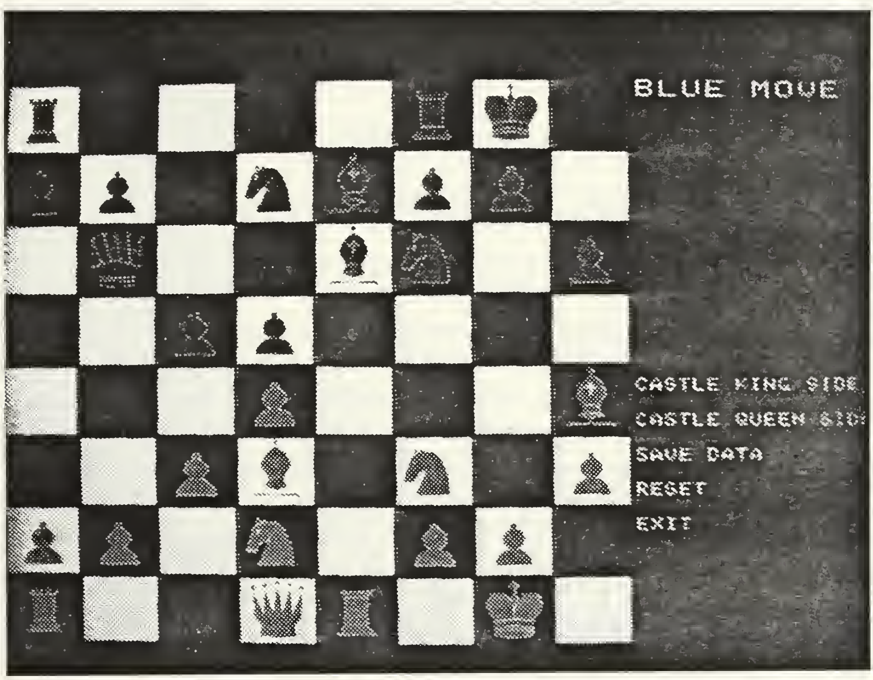


Figure III-4
Initial Graphic Scenario B

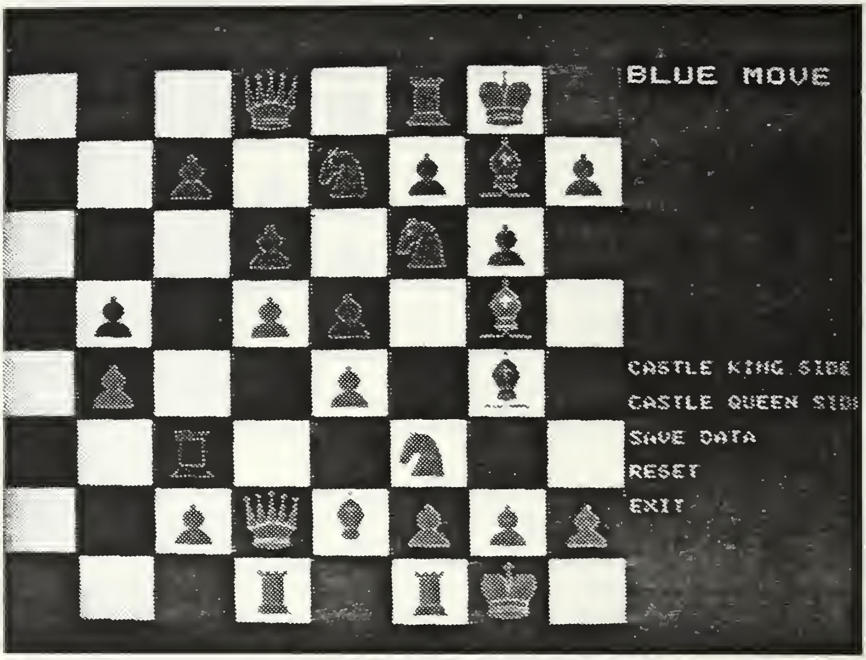


Figure III-5
Initial Graphic Scenario C

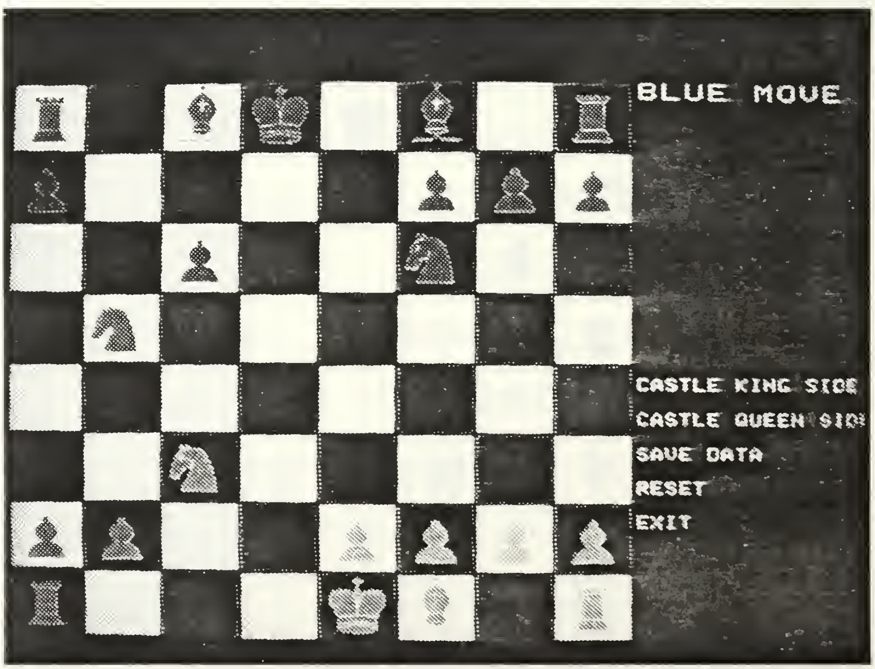


Figure III-6
Initial Graphic Scenario D

plus checkmate score, if the subject won, or a minus checkmate score if the challenger won. An objective was to evaluate affects of levels of information and information representations on measurable subject performance. This could not have been done if all the scores were of the same absolute value. Every game not already in checkmate was played for at least thirteen moves. The subjects did not know a game was actually over after move ten.

3. Subjects

The experiment was conducted in the NPS WAR Lab, a secure computer facility. Access to the WAR Lab required the completion of a current favorable background investigation for a national security clearance. This precluded foreign national students from taking part. Many of these may have been quite knowledgeable in chess. Almost all the participants were NPS students in Command, Control, and Communications or Space Systems Operations curricula. The experiment samples totaled fifty-two subjects. Twenty-six subjects for the color phase and twenty-six subjects for the monochrome phase. There were four civilians. Other than one Air Force Lieutenant Colonel and one Air Force Lieutenant (Captain selectee), the military participants were all senior 03s or 04s. All military participants had recent operational experience. There were ten Army, twenty-six Navy, ten Air Force and two Marine participants. All of

the participants had normal or corrected normal vision. No participants were color blind.

Using the experience level menu descriptions [Figure III-7] which were displayed on the player terminal, eight subjects rated themselves as never having played chess before. Forty subjects rated themselves as novice chess players. Four subjects rated themselves as having played chess frequently. No subjects rated themselves as tournament chess players.

PLEASE ENTER YOUR EXPERIENCE LEVEL

A.-- NEVER HAVE PLAYED CHESS BEFORE
B.-- A NOVICE CHESS PLAYER
C.-- PLAY CHESS FREQUENTLY
D.-- TOURNAMENT CHESS PLAYER

Figure III-7
Experience Level Selection Menu

Participants of the graphic display experiment did not have to know chess notation or basic chess movement statements such as Q/Q1-QB2 meaning advance Queen at (/) Queen1 to (-) Queen's Bishop2 position, or N/Q7*Q/QN6 where N stands for Knight and an "*" means "to take", to make moves. Nevertheless, participants should have had a working knowledge of the game of chess to fully and effectively participate in the experiment. To offset this confounding factor, the designated sample population was informed of the experiment and their expected contribution one academic

quarter before the experiment. The subjects received a briefing and a handout [Appendix B] approximately one month prior to their expected participation. A standard chess game was placed in a common-user area so the participant's could familiarize themselves with the game of chess, or regain any lost proficiency by practicing.

4. Apparatus, Software and Questionnaire

a. Apparatus

The apparatus for the experiment were located in Ingersoll Hall, room IN-157, the NPS WAR Lab. The typical lab configuration proved quite satisfactory for the experiment. Lab partitions and sliding curtains were used to enclose the experiment area. This arrangement allowed the umpire and player to converse and to carry out the experiment with minimal outside distractions. The umpire positioned himself and his equipment so he could observe the display and play of the subjects. The subjects could not see the umpire's display.

The initial interface with the experiment software programs was by means of the DEC VT100 or DEC VT102 video display terminals and keyboards. The game umpire and player each used a terminal to log on the system and call their respective programs and subsequent displays. For the player, the display terminal monitor and keyboard were used only to log on the VAX system, start each trial, and sign off the system at the conclusion of the experiment. The

umpire used the terminal monitor and keyboard more extensively. The umpire had to control the conduct of the experiment and scoring by keyboard entry.

Both the umpire and the player used the graphics display and graphics equipment interface devices. The graphics displays were on RAMTEK GM859C high resolution color monitor screens using 9460 controllers. All chess moves were made using a mouse and tablet interface method.

To provide a consistent challenger for every game, a computerized chess game was used by the experimenter. A subject was not pitted against another subject. Each subject's challenger was a US Chess Federation rated computerized chess game. The computer had perfect knowledge and knew the position of every piece during every move of every game. The computerized chess game formalized the scoring or measure of the performance process. In recent years, several portable computerized chess games have been rated by the US Chess Federation. A highly rated computerized chess game, the Fidelity Electronics Super Sensory "9" Chess Challenger, was used by the umpire. The Chess Challenger had been used for the alphanumeric experiment of O'Bryant and Risney. By using the Chess Challenger, the subjects for the color and monochrome phases were provided the same level of play as the subjects for the alphanumeric experiment. The game scores were derived from the same artificial intelligence

algorithm. This facilitated score comparisons between the graphic and alphanumeric experiments. The Chess Challenger can provide nine playing strengths from training to tournament level. The playing strength is dependent on the amount of time available for the chess program to "think". Training level one was used for the experiments. At level one, the Chess Challenger had an average response time of five seconds for each of its moves. Level one seemed reasonable because the Chess Challenger always had perfect information and the human element, regardless of the information level, was penalized if any turn was not completed within two minutes. Pilot trials for the graphics experiment indicated that level one was adequate. The "challenger" (opponent in the experiment) is rated at approximately 1825--1850 by the US Chess Federation. (Grandmaster rating is equal to 2600 and above. Senior Master rating is 2400 to 2599. Master rating is 2200 to 2399. Expert rating is 2000 to 2199. Class A rating is 1800 to 1999. Class B rating is 1600 to 1799. And, Class C rating is below 1600 points.) The "challenger" equates to a Class A player [Ref. 7].

At level one, for each move, the Chess Challenger would think about and store up to nine anticipated best line of play half-moves. The first move is a countermeasure to predicted move of the subject. The second is the subject's anticipated countermeasure, and so

on. The Chess Challenger uses a Shannon-A Strategy, of iterative search, to calculate all possible moves for both sides up to a set depth. The Shannon-B Strategy, of non-iterative search for new calculations, searches certain moves, without re-calculating already searched moves, to further depths of up to ten or more half-moves.[Ref. 8]

At times, the subjects were unaware of possible threats which simulated the situation wherein a threatening piece could be beyond their sensors' ranges. Without knowledge of the possible threat, a subject's countermeasure was usually not the best or even second best alternative. If this happened, the Chess Challenger could not continue play from its generated repertoire of anticipated moves. Even when the subject picked one of these less likely responses, the Chess Challenger still indicated most of its moves within five seconds.

The Chess Challenger displayed the time taken for each move. This unofficial time was used to inform subjects when they were within thirty seconds of incurring a penalty for not having completed their move. The official time was kept by the VAX system and the chess experiment software programs. The Chess Challenger five second playing time, the two minute time limit for each move by a subject, and the fact that each game was for no more than thirteen moves kept the games to about fifteen minutes each.

b. Software

The software used for the experiments is available on the WAR Lab VAX system in the CHESS directory. The iconic symbol software used for the graphics experiment was written by Risney and Air Force Captain James Tschudy, II. The graphics software uses statements and calls of the Precision Visuals Incorporated DI-3000 graphics software system, as modified by Lawrence Livermore Laboratories. The graphics software displayed red iconic symbols for the challenger chess pieces and blue iconic symbols for the friendly chess pieces. Monochrome-green was made by disconnection of the red and blue color leads to the RAMTEK monitors. The graphic software continuously displayed a menu which facilitated castling and random data saves.

The applications software automatically controlled the presentation and recording of data. Through simple questions and menus, the applications software guided the umpire and player through each trial. The software recorded the trial set up, the player's identification and experience level, the moves made, the official time-to-move, the score entered by the umpire, and the experiment end-game chessboard piece positions. Evaluation scores were recorded after moves eight, nine and ten although these data could be recorded at any point in the game.

c. Questionnaire

At the conclusion of each subject's four trials, the subject completed a questionnaire. The questionnaire was used to remove experimenter speculation during the analysis of the collected data. Appendix D contains a sample questionnaire.

C. CONDUCT OF THE EXPERIMENT

1. Scheduling

The experiment was conducted in the NPS WAR Lab from 19 September to 29 October, 1984. Fifty-minute blocks were allocated to play the 208 games. Pilot trials showed that two games could easily be completed in a fifty-minute block. Therefore, three fifty-minute blocks were planned for each subject to complete the trials and allow for contingencies.

2. Game Preparation

Every subject was expected to be familiarize himself with the game of chess if necessary by availing himself of a chess game which was provided by the author for practice purposes. The subjects were briefed during the academic quarter before the conduct of the experiment and were given a handout [Appendix B]. The handout explained the rationale for the experiment and stated the experimenter's expectations for preparation and participation. The player instructions were abbreviated because the participants had

all used the necessary WAR Lab equipment at one time or another and explicit instructions were not needed.

Prior to a player entering the WAR Lab, the appropriate equipment were arranged and the first displays were initialized for the scheduled participant. When a participant first arrived in the WAR Lab, he or she was questioned about personal preparation, and was told that no outside aids could be used.

A briefing and demonstration was provided concerning the player keyboard entries, the terminal and monitor displays, the use of the keyboard, and the mouse and tablet interface devices. The following instructions were given:

1. They would play four chess games.

2. Each game would have a different scenario and each scenario would be started mid-game.

3. A different level of information would be presented during each game.

4. An overview of the four information levels was given prior to the start of the experiment and prior to each game.

5. Each participant should think of the chess pieces as military elements. A suggestion was tendered that each chess piece should be attributed with characteristics and capabilities in consonance with a given piece's maneuverability. That is, to consider the concepts of line of sight, field of fire, and radar skip zones.

6. Each game would not necessarily be played to its normal conclusion.

7. The player had the first move. A reasonable time to study the initial displays, without penalty, was allowed.

8. If more that two minutes were used for each subsequent move, a point penalty would be assessed. The penalty would not effect the play of the game.

9. Any questions whose answer would not affect play would be answered.

At the conclusion of each game, the subject was asked if he or she wanted to continue and play the next game immediately, or to return later to play the next game.

3. Monitor Displays

The umpire's monitor always displayed a normal chessboard view of the selected scenario. All the chess pieces were shown with the player's pieces in blue and the challenger pieces in red.

The player's monitor displayed pieces according to the scenario and information level criteria selected by the umpire. If the subject was to play the games in color, the chessboard surface consisted of black and white squares. The subject's chess pieces were shown in blue and the visible challenger chess pieces were shown in red. If the subject was to play the game in monochrome-green, the chessboard surface was monochrome-green and black. All the visible chess pieces in the monochrome experiment were the same "color". For the monochrome experiment, the visible challenger chess pieces were identified for the player prior to starting each game. Thereafter, it was up to the player to remember, or determine, which piece(s) was friendly. A player could not move a challenger piece, but

identification of friend or foe was not trivial. The player could capture his own chess piece. In four of the monochrome-green games, a player's own chess piece was "taken" by friendly fire.

Examples of three of the four information levels are shown in graphic form in Figures III-8 to III-10. Information level three examples are shown in Figures III-3 through III-6. To reiterate, 1 represents the least amount of information, and 4 represents the greatest amount of information. The displays for the least amount of information showed the subject's chess pieces and only those enemy pieces which could be attacked. For level 2, the basic displays were the same as for level 1 with safe squares identified. For level 3, all chess pieces were displayed. For level 4, safe squares and vulnerable enemy pieces were identified, and all the chess pieces were shown.

Additional graphics displays are shown by scenario and selected information levels in Figures III-11 to III-13.

4. Game Turn

The first move of every game was made by the player. The player's monitor always displayed the current disposition of all appropriate chess pieces.

A game turn consisted of a move by the player followed by a move by the umpire. The subject would move the mouse on the tablet until a cross-hair was on the piece he or she desired to move, or on a menu item, as

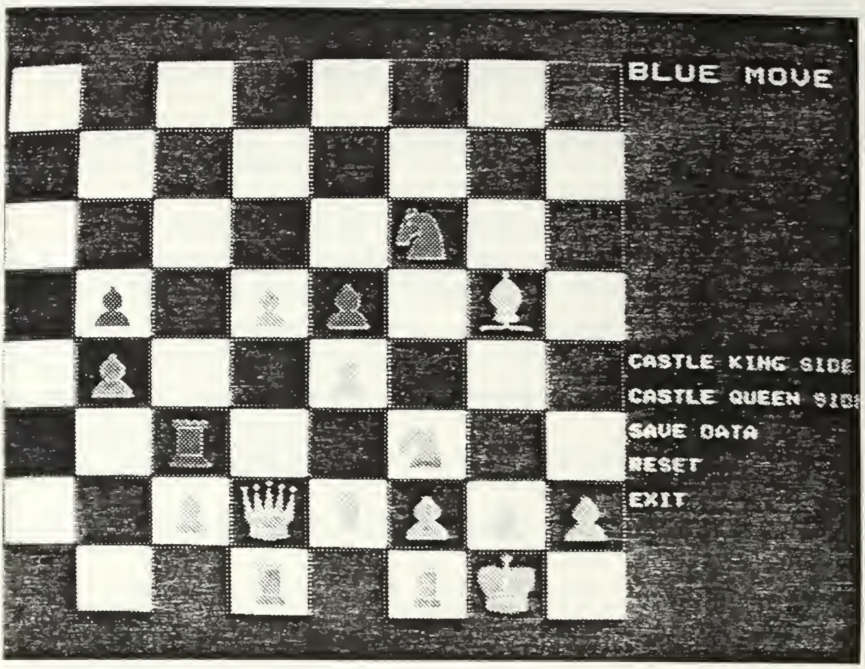


Figure III-8
Graphic Information Level 1

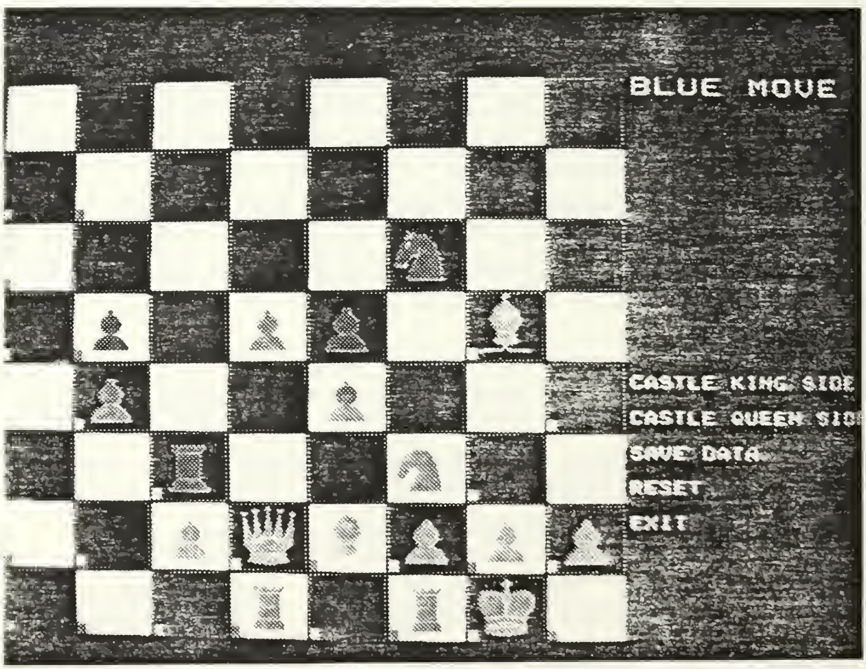
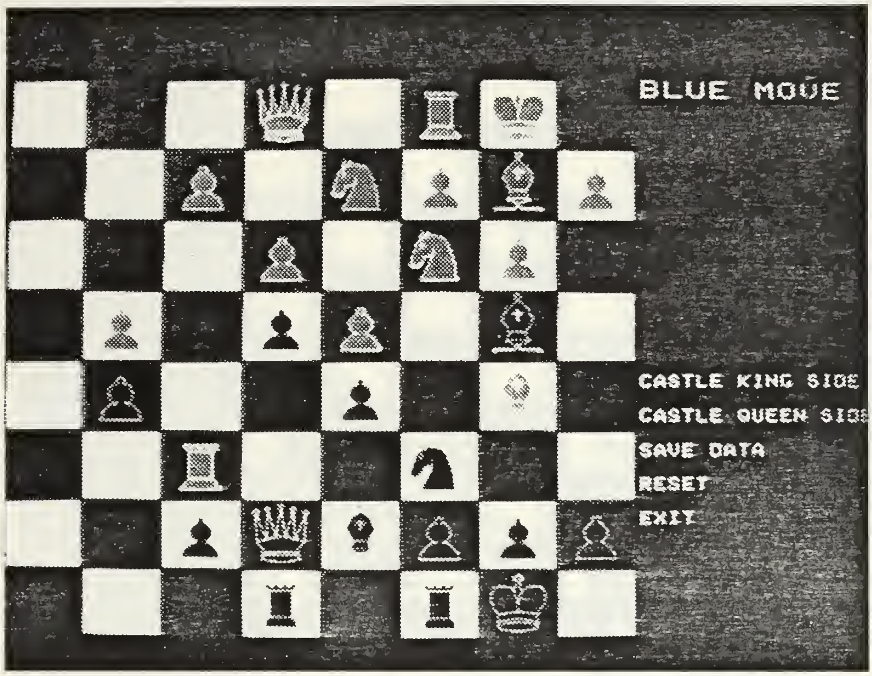
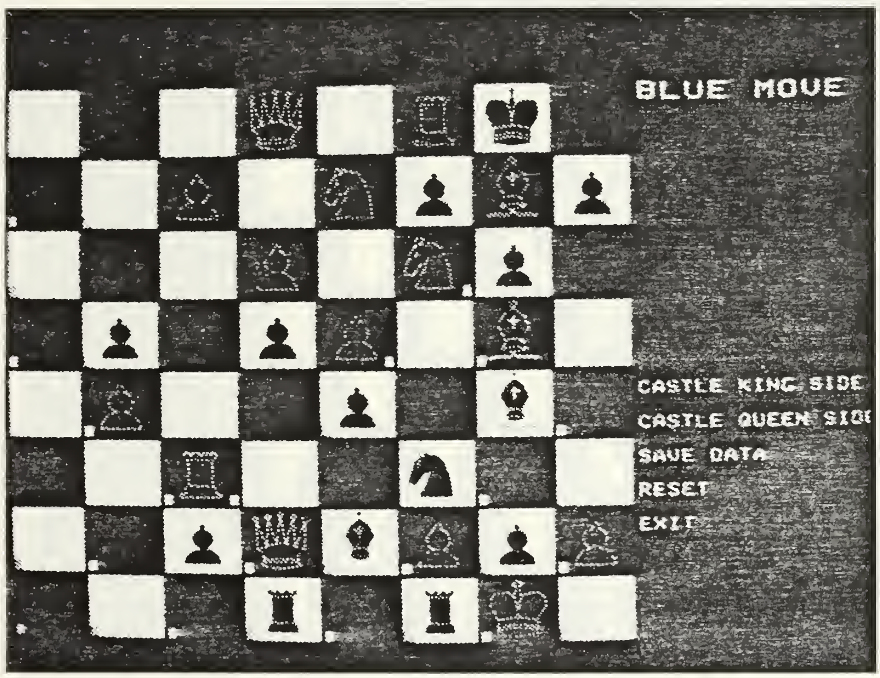


Figure III-9
Graphic Information Level 2

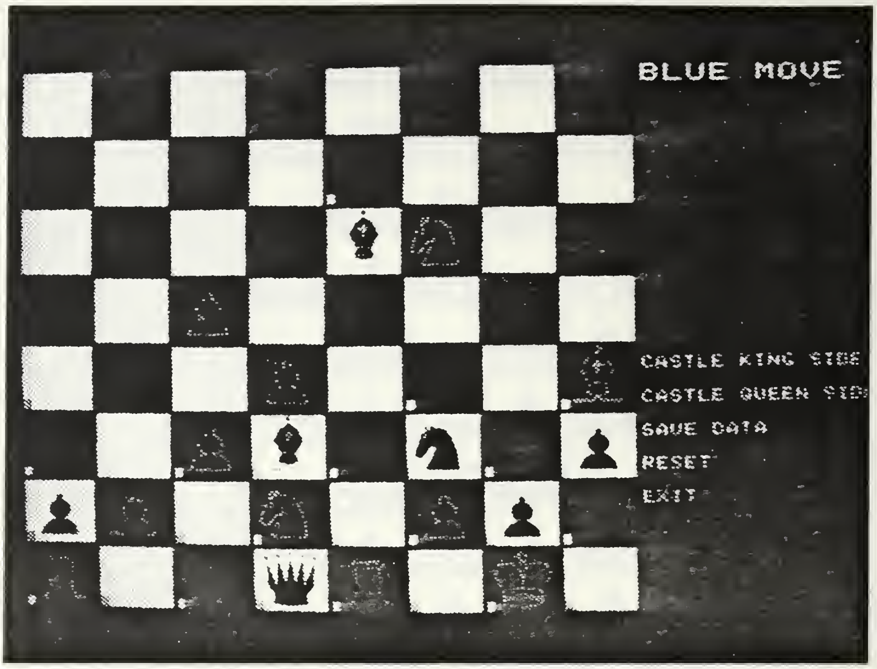


Color Scenario 3

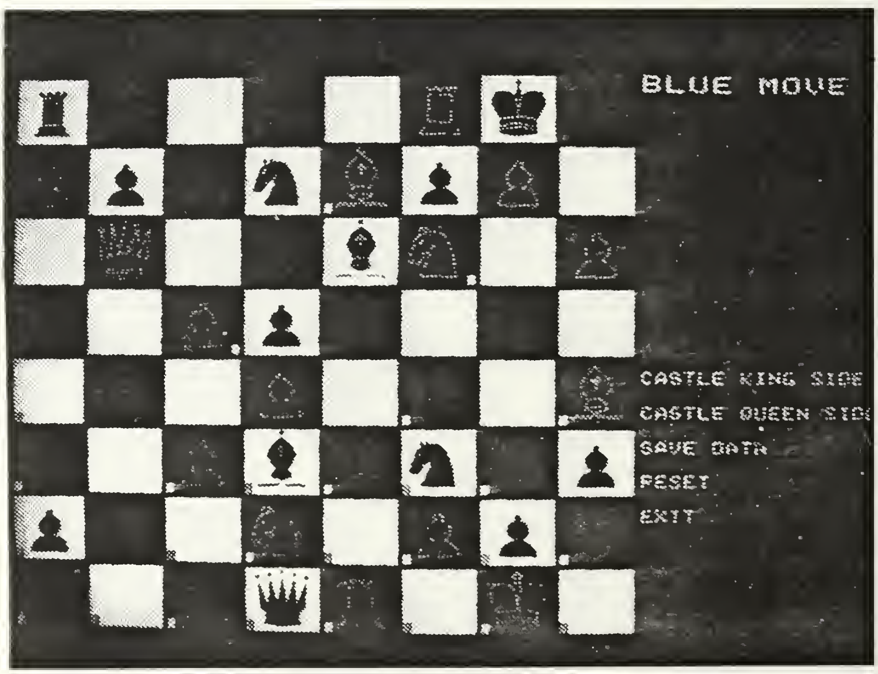


Monochrome Scenario 3

Figure III-10
Graphic Information Level 4

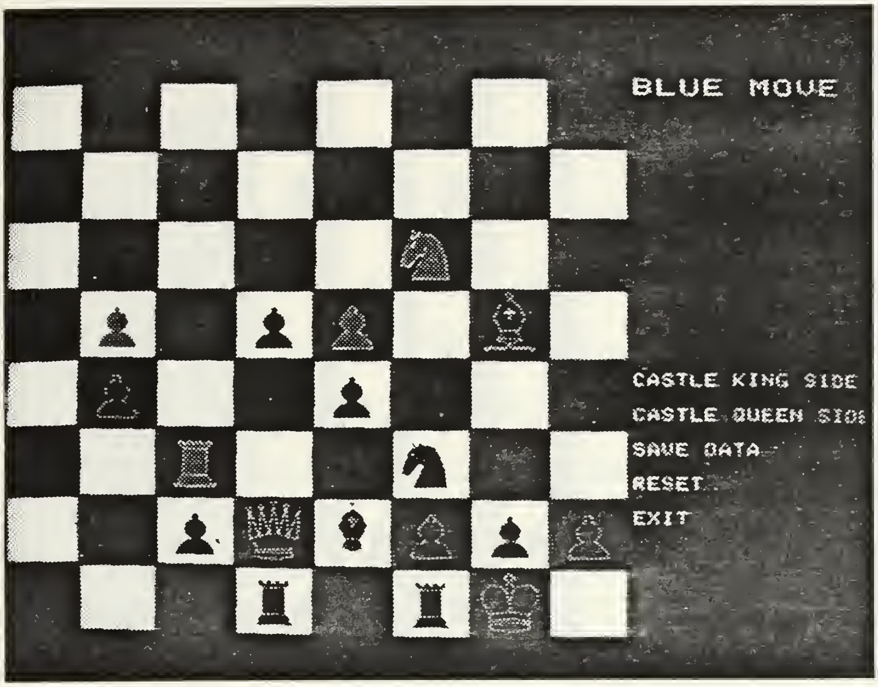


Monochrome Level 2

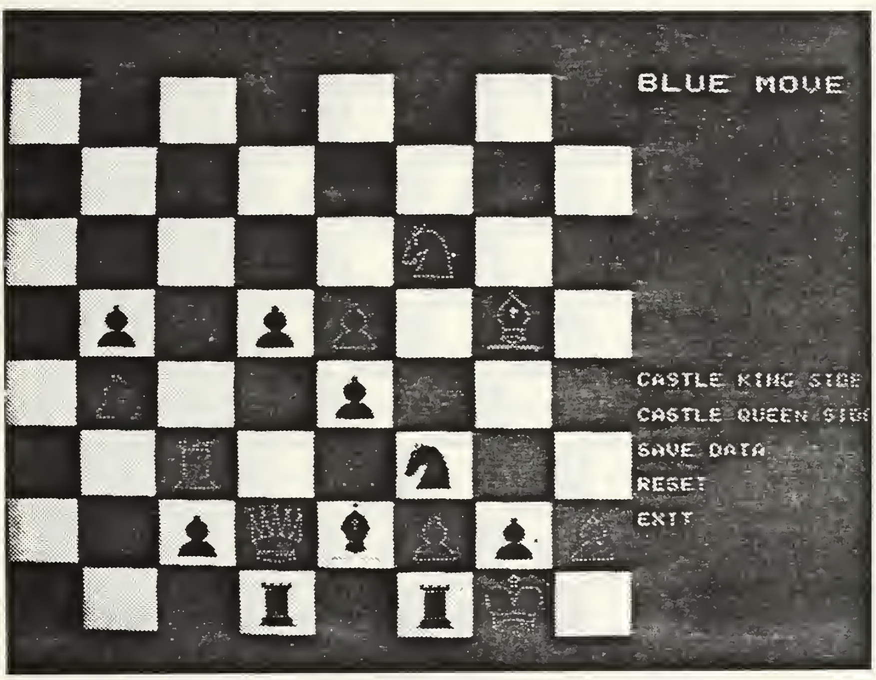


Monochrome Level 4

Figure III-11
Selected Scenario 2 Graphic Displays

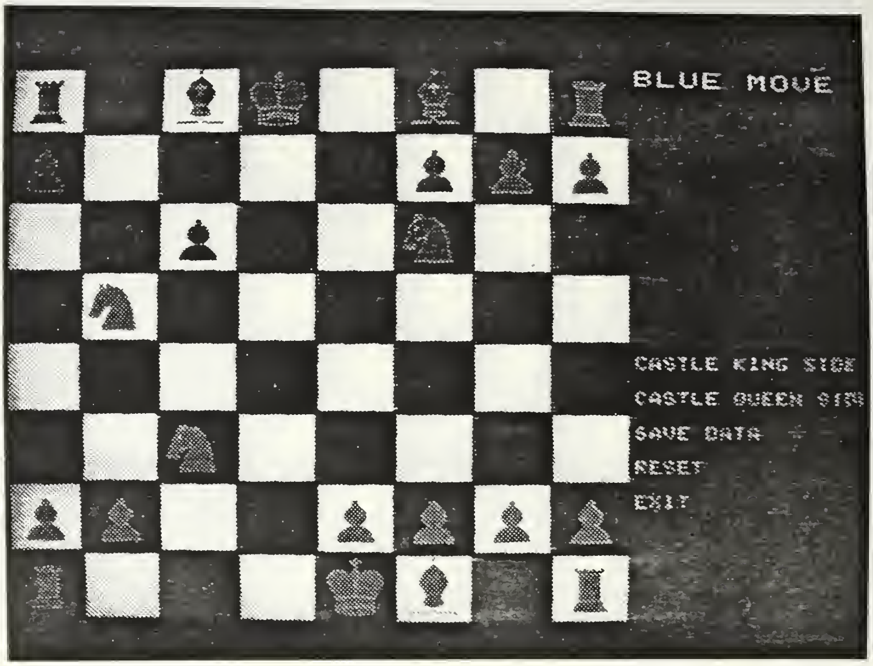


Color Level 1

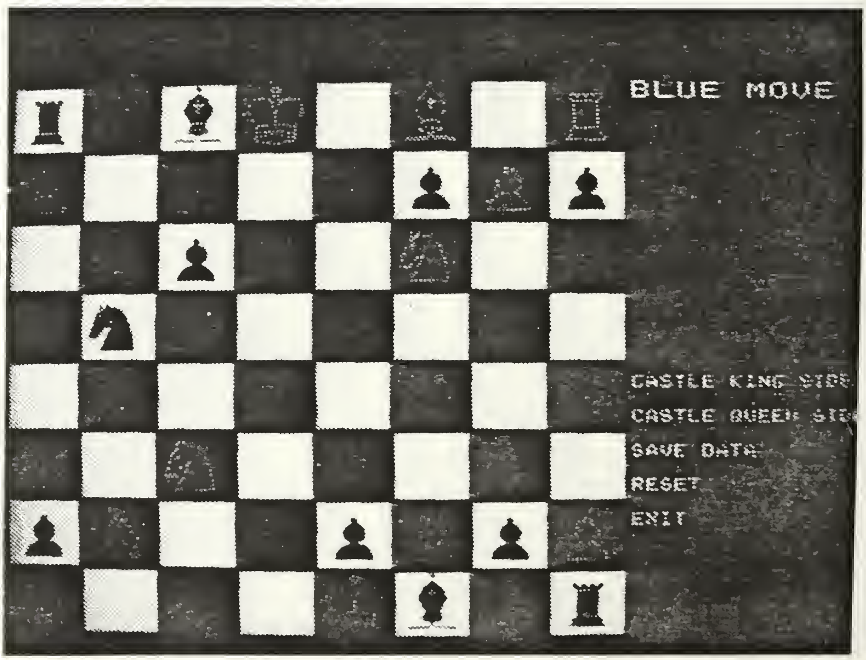


Monochrome Level 1

Figure III-12
Selected Scenario 3 Graphic Displays



Color Level 3



Monochrome Level 3

Figure III-13
Selected Scenario 4 Graphic Displays

appropriate. The subject pressed a button on the mouse to indicate to the computer which piece to move. The player moved the cross-hair to a square to which he or she desired to move the marked piece, and again signaled the computer by pressing a button on the mouse. If the indicated move was legal, the computer's internal clock stopped. The time taken for the move was saved. The indicated piece disappeared from its current position and reappeared in the selected square. After a player completed a move, control was immediately transferred to the umpire's devices and displays. At all times, the umpire's monitor display showed the current disposition of all the chess pieces.

The umpire used the same type of computer devices and the Chess Challenger. To make a move, the current positions of the chess pieces were noted and the Chess Challenger chess pieces were positioned accordingly. Within approximately five seconds, the Chess Challenger indicated which of the challenger pieces to move and where to move it. The Challenger's move was indicated to the main computer with mouse and tablet devices the same way the player indicated his move. If the challenger's intended move completed game move eight, nine, or ten, or there was a desire to save the current monitor display and enter a score, the Chess Challenger was again used. A hexadecimal score was obtained from the Chess Challenger and entered into the main computer system with the terminal keyboard.

Any move registered by the subject or umpire, if it was a legal move, was final. There was no provision for taking back or changing a move once it was indicated to the system. This simulated the reality of a commitment of forces.

5. Subject

The player's terminal was initialized by the umpire. For each game, the player used the keyboard to select a RAMTEK monitor on which the appropriate displays would appear. The player entered a name with which to be identified. This name was used to collocate the data collected from an individual participant's four games. The player entered his or her skill level using menu [Figure III-7] definitions.

Once the game began, the player observed the RAMTEK monitor display and interfaced using the mouse and tablet.

6. Experimenter

The experimenter performed several tasks prior to and during the administration of each game [Appendix C]. All appropriate WAR Lab devices were checked to see if they were properly connected and interconnected electrically. The physical location of pertinent equipment was checked to ensure it was in accord with the experiment equipment configuration design. If a game was to be in monochrome-green, the red and blue color leads to the player's RAMTEK monitor were disconnected. If a session entailed more than

one game, a single check of the equipment and configuration usually sufficed unless a subsequent game required the connection, or disconnection, of the red and blue leads. The experimenter logged the player onto the computer system and made the player terminal ready for player provided input. The experimenter then returned to the umpire position to log on a terminal.

The umpire displays consisted of menus and simple answer questions to call the appropriate displays for each game. The intended graphics displays would appear on the umpire and player RAMTEK monitors simultaneously.

Before commencing each game, the player was briefed. Questions were fielded from the player, and time was given for the player to study the monitor display while the umpire set up the Chess Challenger game board. When the player indicated he or she was ready, the game officially began.

After each subject finished playing four games, the experimenter gave the subject a questionnaire [Appendix D] to be completed and returned to the experimenter as soon as possible.

D. SUMMARY

This chapter provided a concise description of the methodology, the design and conduct, of the graphic experiment. The graphic experiment was designed to replicate the O'Bryant and Risney alphanumeric experiment so

the data from both experiments could be compared and analyzed more readily.

IV. ANALYSIS

A. OVERVIEW

Raw data were collected and collated from the alphanumeric and graphic experiments. The collected raw data is stored in the WAR Lab computer system and on a backup tape available in the WAR Lab.

A score (MOE) was computed for each game by a multi-step process:

1. The opening game material and positional values were computed for each of the four scenarios.

2. The game score was normalized by subtracting the appropriate opening game value.

3. Penalty points, if any, were computed. Times greater than 120 seconds for the second through tenth move were summed and divided by 60. This value was rounded up to a whole number. The whole number was multiplied by the value of one Pawn (-256). The result was the number of penalty points to assess.

4. The game MOE was the normalized score plus any penalty.

The value chosen for checkmate was -32753. The instruction booklet for the Super Sensory "9" Chess Challenger suggests this game score for checkmate.

The game scores were entered manually into three data files for analysis on an International Business Machines (IBM) 3033 (the statistical program used for analysis was on the NPS common user IBM system; the data could not be electrically transferred between the DEC and the IBM systems

for security reasons). The data files contain five columns. Column one contains the subject identification numbers. The names of the subjects were used only to schedule participants and provide a check to ensure each subject played four games. Column two shows the subject's self evaluation of skill level. Column three is the numeric intelligence level or amount of information. Column four is the number of the scenario. Column five contains the adjusted game score in decimal form. Each file shows the data by trial number. Table III-1 is the data file for the color phase of the graphic experiment, Table III-2 is the data file for the monochrome phase of the graphic experiment, and Table III-3 is the data file for the alphanumeric experiment as used in my analysis.

Preliminary analyses of the data, doing number lines, scatter diagrams, histograms, frequency polygons, and deterministic statistics (finding mean, mode, and median) identified outliers. The outliers were scores reflecting checkmate or imminent checkmate. The outlier scores were randomly dispersed throughout the data files. The outlier scores, five from each data file, were dropped. To leave these scores in the data base would have resulted in variances so large as to make impossible the detection of any significant differences in the factors of interest.

The data files were arranged and combined for computer assisted analysis. For the computer analysis, the data were

ordered and manipulated to fit the analysis program and memory space allotted to users. The scores were divided by -100 to make the numbers more manageable.

Several statistical packages are available at NPS for analyzing data. Interactive Statistical Computing (MINITAB), Statistical Programs for the Social Sciences (SPSS), Statistical Analysis System (SAS), and others were looked at and rejected. For the statistical analysis of the collected and collated data, the author used an analysis of variance (ANOVA) computer program developed by Professor Richards. The program is written using A Programming Language (APL).

Richards' program uses the entire model and then may repeat the ANOVA on a reduced model. If omitted data or interacting variables prevent the use of the full model, the program reverts to a reduced model. The algorithm systematically omits the factors under investigation which have the smallest importance in explaining the data. The main table produced by the ANOVA program lists the R-Square, the Source of Variation, Degrees of Freedom (DF), Sum of Squares (SS), Mean Square (MS), calculated F-test statistic, and Significance. The ANOVA table factors are individually evaluated and tabulated as Main Effect data.

B. ANALYSIS DISCUSSION

The ANOVA program was run separately for the color, monochrome, and alphanumeric data. It was also run using the data collated from both the alphanumeric and the graphic experiments. Therefore, the same format is used for reporting the analysis of the data for ease of reading, understanding, and comparison.

The null hypothesis (H_0) for each case is that the factor had no effect on the test scores. For each factor an F-statistic is presented and a significance level is determined. The significance level indicates the probability that a value of the F-statistic as large as that computed could have resulted due to randomness if the null hypothesis were true. For the discussion purposes, we selected a significance level of .05, a confidence interval of .95, to base our decision about rejection of the hypothesis.

Comments on the Main Effect data for the significant ANOVA table factors follow the appropriate factor discussion. All the factors and main effect data are discussed in the analysis of the grouped data for comparison purposes.

Questionnaire responses are discussed separately. In general, chess is an anticipatory game which normally allows prediction with a degree of certainty. With degradation of information (less than the normal chessboard view),

prediction was nearly impossible. But, the levels of information were intended to simulate battlefield conditions, and they do. This is most evident when the information levels are compared with submarine warfare or military countermeasures to insurgence.

C. DISCUSSION

1. Color Experiment

Table IV-1 is the ANOVA table and Main Effect data for the color phase of the graphics experiment.

a. Intelligence

At a 95% confidence level, intelligence (the amount of information) has an effect on the MOE.

(1) Intelligence Main Effect. Subjects did best with the normal view of the chessboard. They did worst with the least amount of information. The difference between worst and best is significant. There is very little difference in scores between information levels 2, 3, and 4.

b. Scenario

At a 95% confidence level, the scenario has an effect on the MOE.

(1) Scenario Main Effect. Subjects did best with scenario 2. They did worst with scenario 3. The difference between scenario 2 and 3 is significant. There is very little difference in scores between scenarios 1, 2, and 4.

TABLE IV-1

COLOR EXPERIMENT ANOVA TABLE

COLOR CHESS EXPERIMENT

R-SQUARE = .3516

SOURCE OF VARIATION	DF	SS	MS	F	SIG
TOTAL	98.	22169.861	226.223		
ERROR	87.	14375.015	165.23		
MODEL	11.	7794.846	708.622	4.289	0.0
FACTOR 1. INTELLIGENCE	3.	1391.723	463.908	2.808	0.044
FACTOR 2. SCENARIO	3.	3054.62	1018.207	6.162	0.001
FACTOR 3. TRIAL	3.	357.888	119.296	0.722	0.541
FACTOR 4. EXPERIENCE	2.	2445.732	1222.866	7.401	0.001

MAIN EFFECT 1:

LEVEL	COUNT	MEAN
1	22	31.9609
2	25	23.1156
3	26	21.4196
4	26	22.3100

MAIN EFFECT 2:

LEVEL	COUNT	MEAN
1	25	23.0848
2	25	19.1292
3	24	34.8067
4	25	21.0916

MAIN EFFECT 4:

LEVEL	COUNT	MEAN
1	15	36.2407
2	80	22.1387
3	4	25.8225

c. Trial

At a 95% confidence level, the trial has no effect on the MOE. This was as desired as it suggests that learning was not a significant factor.

d. Experience

At a 95% confidence level, the experience of a player has an effect on the MOE.

(1) Experience Main Effect. Level 2 subjects did the best. Level 1 subjects did the worst. The difference between level 1 and 2 is significant. There is little difference in scores for level 2 and 3 subjects. The reason for level 2 subjects doing better than level 3 is probably due having only one level 3 subject.

2. Monochrome Experiment

Table IV-2 is the ANOVA table and Main Effect data for the monochrome phase of the graphics experiment.

a. Intelligence

At a 95% confidence level, intelligence has an effect on the MOE.

(1) Intelligence Main Effect. Subjects did best with the most amount of information presentation. They did worst with the least amount of information. The difference between worst and best is significant. There is a significant difference in scores attained with information levels 2 and 3, and those with information levels 1 and 4.

TABLE IV-2

MONOCHROME EXPERIMENT ANOVA TABLE

MONOCHROME CHESS EXPERIMENT

R-SQUARE = .3311

SOURCE OF VARIATION	DF	SS	MS	F	SIG
TOTAL	98.	18964.259	193.513		
ERROR	87.	12684.798	145.802		
MODEL	11.	6279.461	570.86	3.915	0.0
FACTOR 1. INTELLIGENCE	3.	2845.074	948.358	6.504	0.0
FACTOR 2. SCENARIO	3.	390.873	130.291	0.894	0.448
FACTOR 3. TRIAL	3.	388.635	129.545	0.888	0.45
FACTOR 4. EXPERIENCE	2.	2385.028	1192.514	8.179	0.001

MAIN EFFECT 1:

LEVEL	COUNT	MEAN
1	25	31.3120
2	25	23.6840
3	25	20.2680
4	24	15.8942

MAIN EFFECT 2:

LEVEL	COUNT	MEAN
1	24	22.6725
2	26	22.5719
3	24	26.3254
4	25	20.0096

MAIN EFFECT 4:

LEVEL	COUNT	MEAN
1	12	33.0533
2	75	22.9729
3	12	11.9542

b. Scenario

At a 95% confidence level, the scenario has no effect on the MOE. This falsely suggests that monochrome displays are better because the scenario significantly affected the scores in the color phase and the alphanumeric experiment. Although the monochrome phase subjects did best with scenario 4 and worst with scenario 3, the difference is not significant. The scenario 3 scores were better than the non-monochrome scenario 3 scores. This can probably be explained by the fact that the monochrome phase required more concentration. In the non-monochrome games, a probable lack of concentration caused oversight, resulted in the loss of major friendly pieces, and the subjects could not recover from the losses as reflected in the bad scores.

c. Trial

At a 95% confidence level, the trial has no effect on the MOE.

d. Experience

At a 95% confidence level, the experience of a player has an effect on the MOE.

(1) Experience Main Effect. Level 3 subjects did the best. Level 1 subjects did the worst. The difference between levels 1, 2, and 3 is significant.

3. Alphanumeric Experiment

Table IV-3 is the ANOVA table and Main Effect data for the alphanumeric experiment.

TABLE IV-3

ALPHANUMERIC EXPERIMENT ANOVA TABLE

ALPHANUMERIC CHESS EXPERIMENT

R-SQUARE = .2601

SOURCE OF VARIATION	DF	SS	MS	F	SIG
TOTAL	117.	25950.349	221.798		
ERROR	106.	19201.607	181.147		
MODEL	11.	6748.742	613.522	3.387	0.0
FACTOR 1. INTELLIGENCE	3.	741.131	247.044	1.364	0.258
FACTOR 2. SCENARIO	3.	4958.23	1652.743	9.124	0.0
FACTOR 3. TRIAL	3.	525.623	175.208	0.967	0.411
FACTOR 4. EXPERIENCE	2.	371.968	185.984	1.027	0.362

MAIN EFFECT 2:

LEVEL	COUNT	MEAN
1	30	19.6843
2	31	25.8965
3	28	35.4200
4	29	18.7634

a. Intelligence

At a 95% confidence level, intelligence has no effect on the MOE.

b. Scenario

At a 95% confidence level, the scenario has an effect on the MOE.

(1) <u>Scenario Main Effect</u>. Subjects did best with scenario 4. They did worst with scenario 3. The difference between scenario 3 and 4 is significant. There is very little difference in scores between scenarios 1 and 4. Scenario 2 resulted in a mid-range score.

c. Trial

At a 95% confidence level, the trial has no effect on the MOE.

d. Experience

At a 95% confidence level, the experience of a player has no effect on the MOE.

4. <u>Grouped Data</u>

Table IV-4 is the ANOVA table and Main Effect data for the grouped data of the graphics and alphanumeric experiments.

a. Intelligence

At a 95% confidence level, intelligence has an effect on the MOE.

(1) <u>Intelligence Main Effect</u>. Subjects did best with the most amount of information. They did worst

TABLE IV-4

GROUPED DATA ANOVA TABLE

GROUPED DATA

R-SQUARE = .2426

SOURCE OF VARIATION	DF	SS	MS	F	SIG
TOTAL	315.	67309.044	213.68		
ERROR	302.	50982.27	168.815		
MODEL	13.	16326.774	1255.906	7.44	0.0
FACTOR 1. INTELLIGENCE	3.	4473.396	1491.132	8.833	0.0
FACTOR 2. SCENARIO	3.	6793.42	2264.473	13.414	0.0
FACTOR 3. TRIAL	3.	434.523	144.841	0.858	0.463
FACTOR 4. EXPERIENCE	2.	3905.958	1952.979	11.569	0.0
FACTOR 5. PRESENTATION	2.	298.997	149.499	0.886	0.414

MAIN EFFECT 1:

LEVEL	COUNT	MEAN
1	75	31.0465
2	79	23.2156
3	82	21.3155
4	80	21.2486

MAIN EFFECT 2:

LEVEL	COUNT	MEAN
1	79	21.6682
2	82	22.7791
3	76	32.3543
4	79	19.8946

MAIN EFFECT 4:

LEVEL	COUNT	MEAN
1	37	32.3989
2	251	23.6161
3	28	17.2814

MAIN EFFECT 5:

LEVEL	COUNT	MEAN
1	99	24.4242
2	99	22.8592
3	118	24.8239

with the least amount of information. The difference between worst and best is significant. The differences between levels 2, 3, and 4 are not significant.

b. Scenario

At a 95% confidence level, the scenario has an effect on the MOE.

(1) <u>Scenario Main Effect</u>. Subjects did best with scenario 4. They did worst with scenario 3. The difference between scenario 3 and 4 is significant. There is very little difference in scores between scenarios 1, 2, and 4. For the subjects to do worst with scenario 3 was expected. The scenario was such that the subject's Queen or other significant chess pieces were immediately in jeopardy. In a sense, the beginning of the game simulated an initial graphic display (briefing) of an imminent multi-pronged attack. Within a couple of moves, the subject's Queen or a few other major pieces were gone. The scores show that effective recovery was not possible.

c. Trial

At a 95% confidence level, the trial has no effect on the MOE.

d. Experience

At a 95% confidence level, the experience of a player has an effect on the MOE.

(1) <u>Experience Main Effect</u>. Level 3 subjects did the best. Level 1 subjects did the worst. the

difference between level 1 and 3 is significant. Level 2 subjects' scores were about midway between the scores for the other levels. Level 3 subjects were expected to do better. However, the difference in scores for level 2 and 3 participants, although not statistically significant, were larger than expected by the author.

e. Presentation

At a 95% confidence level, the method of representing information has no effect on the MOE.

D. QUESTIONNAIRE RESPONSES

1. Overview

A questionnaire was developed to assist in the evaluation of results of the graphics chess experiment. Appendix F contains a sample questionnaire. All the subjects rated themselves on the aggressiveness of their play. They also rated themselves on the use of additional information. Additional information was provided for information levels 2 and 4. In level 2, safe squares were marked. In level 4, safe squares and vulnerable enemy pieces were identified. Discussions with the players at the conclusion of the four games and written comments on the questionnaire provided insight to the play of the games.

2. Color Experiment

Table IV-5 shows results of the questionnaire regarding usage of available information. Over fifty

TABLE IV-5

COLOR QUESTIONNAIRE RESULTS: INFORMATION

************** Level 2 Use of Information **************

Use of Information	Percent	Number
Not at all	4	1
For few moves	4	1
For half the moves	12	3
For most moves	58	15
For all moves	27	7

************** Level 4 Use of Information **************

Use of Information	Percent	Number
Not at all	4	1
For few moves	8	2
For half the moves	23	6
For most moves	54	14
For all moves	12	3

NOTE: Rounded percentages are used in the tables and some totals may not equal 100%.

percent of the subjects used the additional information for most of their moves. A few subjects used the information very little, or not at all. Experienced players filtered what they considered extraneous information. They also filled information gaps and played against probable challenger pieces and strategy. There was not a significant difference between the use of additional information between levels 2 and 4.

Table IV-6 shows the aggressiveness of the subjects for each level of information presented. For three of the information levels, subjects tended to become somewhat or more aggressive toward the end of a game. With information level 4, the subjects tended to become somewhat offensive in their play.

3. Monochrome Experiment

Table IV-7 shows results of the questionnaire regarding usage of available information. All the subjects used the additional information when it was provided. Over fifty percent used the additional information for most of their moves. Again, experienced players filtered what they considered extraneous information. They also filled information gaps and played against probable challenger pieces and strategy. There was not a significant difference between the use of additional information between levels 2 and 4.

TABLE IV-6

COLOR QUESTIONNAIRE RESULTS: AGGRESSIVENESS

************** Level 1 Aggressiveness **************

Rating	Beginning of game Percent	Beginning of game Number	Toward end of game Percent	Toward end of game Number
Very defensive	19	5	19	5
Somewhat defensive	31	8	31	8
Neutral	23	6	31	8
Somewhat offensive	15	4	15	4
Very offensive	12	3	4	1

************** Level 2 Aggressiveness **************

Rating	Beginning of game Percent	Beginning of game Number	Toward end of game Percent	Toward end of game Number
Very defensive	19	5	19	5
Somewhat defensive	27	7	31	8
Neutral	31	8	15	4
Somewhat offensive	15	4	27	7
Very offensive	8	2	8	2

************** Level 3 Aggressiveness **************

Rating	Beginning of game Percent	Beginning of game Number	Toward end of game Percent	Toward end of game Number
Very defensive	15	4	8	2
Somewhat defensive	27	7	42	11
Neutral	12	3	19	5
Somewhat offensive	42	11	27	7
Very offensive	4	1	4	1

************** Level 4 Aggressiveness **************

Rating	Beginning of game Percent	Beginning of game Number	Toward end of game Percent	Toward end of game Number
Very defensive	4	1	12	3
Somewhat defensive	27	7	27	7
Neutral	31	8	19	5
Somewhat offensive	27	7	31	8
Very offensive	12	3	12	3

NOTE: Rounded percentages are used in the tables and some totals may not equal 100%.

TABLE IV-7

MONOCHROME QUESTIONNAIRE RESULTS: INFORMATION

************* Level 2 Use of Information **************

Use of Information	Percent	Number
Not at all	0	0
For few moves	8	2
For half the moves	12	3
For most moves	50	13
For all moves	31	8

************* Level 4 Use of Information **************

Use of Information	Percent	Number
Not at all	0	0
For few moves	27	7
For half the moves	15	4
For most moves	50	13
For all moves	8	2

NOTE: Rounded percentages are used in the tables and some totals may not equal 100%.

Table IV-8 shows the aggressiveness of the subjects for each level of information presented. For three of the information levels, subjects tended to become somewhat or more aggressive toward the end of a game. With information level 3, the subjects tended to become somewhat to very defensive in their play.

E. SUMMARY

This chapter provided an in depth analysis of the collected data and the questionnaire. The effects and significance of the model factors were represented by ANOVA tables and Main Effect data. The factors and main effects of significant factors were discussed.

The following chapter discusses the conclusions and recommendations.

TABLE IV-8

MONOCHROME QUESTIONNAIRE RESULTS: AGGRESSIVENESS

************* Level 1 Aggressiveness **************

Rating	Beginning of game Percent	Beginning of game Number	Toward end of game Percent	Toward end of game Number
Very defensive	27	7	31	8
Somewhat defensive	31	8	42	11
Neutral	27	7	4	1
Somewhat offensive	12	3	19	5
Very offensive	4	1	4	1

************* Level 2 Aggressiveness **************

Rating	Beginning of game Percent	Beginning of game Number	Toward end of game Percent	Toward end of game Number
Very defensive	23	6	19	5
Somewhat defensive	35	9	23	6
Neutral	15	4	8	2
Somewhat offensive	23	6	42	11
Very offensive	4	1	8	2

************* Level 3 Aggressiveness **************

Rating	Beginning of game Percent	Beginning of game Number	Toward end of game Percent	Toward end of game Number
Very defensive	13	3	8	2
Somewhat defensive	35	9	35	9
Neutral	35	9	15	4
Somewhat offensive	15	4	38	10
Very offensive	4	1	4	1

************** Level 4 Aggressiveness **************

Rating	Beginning of game Percent	Beginning of game Number	Toward end of game Percent	Toward end of game Number
Very defensive	12	3	8	2
Somewhat defensive	31	8	15	4
Neutral	35	9	23	6
Somewhat offensive	15	4	46	12
Very offensive	8	2	8	2

NOTE: Rounded percentages are used in the tables and some totals may not equal 100%.

V. CONCLUSIONS AND RECOMMENDATIONS

A. OBJECTIVE REVIEW

This study was an investigation of the effects of three different ways of representing four different amounts of information. The information was represented by alphanumeric, color graphic, or monochrome-green graphic displays. The study used a variation of the game of chess as a war game requiring sequential decision making. The play of the games and collection of data was computer controlled. Each game was terminated at a predetermined move and a game score was derived. The score reflected the quality of the decisions made in a conflict environment. The game score was used as the measure of effectiveness (MOE).

B. CONCLUSIONS

1. Empirical Conclusions

The reporting of decisions made was much quicker in the graphics experiment than in the alphanumeric experiment. The reason for this could be attributed to one or a combination of two factors.

Although the grouped data indicated no measurable differences in scores due to the method of presentation, it appears that the subjects could comprehend a level of

information in graphic form much faster than when the same information was presented in alphanumeric form. The time taken to make decisions known was much less in the graphics experiments than in the alphanumeric experiment. The average time difference could be explained by the manner in which the decision was communicated. The subjects in the alphanumeric experiment were required to enter their decisions in standard chess format using a keyboard. Familiarity with the standard chess format and typing skill could have accounted for the difference in the perceived time to report. The subjects in the graphics experiments used a mouse and tablet to report decisions made. A mouse and table greatly facilitated quick reporting of decisions made. A second button push on the mouse completed the two step sequence necessary to make most moves. The computer program translated the button pushing to standard chess nomenclature. This is comparable to sending formatted messages where a button push or two puts routing instructions and a heading on a message.

The conclusion is that coding facilitates data transfer. For the most efficient and effective communication to take place, the following must happen. The sender must be able to indicate which data elements are to be in the intended message in a way he or she has competence. The data elements are collected, encoded, and transmitted. Some mechanism receives the transmission and

decodes the data into a form comprehensible to the recipient. The decision made by the recipient is the feedback showing if communication took place. Communication takes place when intended messages are acted upon in accord with the senders intentions.

2. <u>No Optimal Amount of Information was Used</u>

Four different levels of information were used in the experiments. If one of these would have been optimal, its presentation would have resulted in the best MOE.

The concept of information overload can be described by two regions: (1) As input increases from zero, the amount of output goes from zero and increases almost linearly to a threshold region. (2) If there is more input, the amount of output decreases.

When an overload occurs, the sensory capacities and capabilities have been overtaxed. The consequence of additional information is manifested in several forms. Organisms succumb to, compensate for, or cope with an excess of information several ways. A person can ignore it, filter it, selectively pick and choose available input, or group input in synopsized, comprehensible chunks. The object of doing something positive is to get back on the rising portion of the information overload curve. In all cases performance decreases and the result is a decrease in the quality of decisions made.

With decision making, less than the essential amount or an overload of information results in less than optimal decisions. With sequential decision making, the probability of repeatedly correctly guessing and filling in several information gaps, or correctly selecting from a multitude of data, is infinitesimal. Although humans are creative, the end result is a low quality decision made.

3. Factors Affecting Use of Information

Experience of the user, the scenario or situation, and the method of representing information effect the utility of an amount of information.

Experienced decision makers compensate if the amount of received information is not optimal. Experienced decision makers fill in gaps when there is a deprivation of information needed to make a quality decision. They filter, or selectively use available information when the information provided is more than they need to make a quality decision.

The beginning scenario or situation may cause the decision maker to misapply resources. Regardless of the amount of information available, the initial situation may have too many variables requiring the decision makers attention. If the decision maker ignores or overlooks a variable he or she has a contingency. The value of experience in decision making is in having coped with past contingencies. We never have perfect information. The

question is not whether we will pass from planned action to experienced reaction, but when will such a transition be required, and has our training and experience prepared us for the eventuality.

The method of representing information affected the information overload threshold. An amount of information in alphanumeric form which causes an information overload may not cause an overload if it is represented in monochrome graphic form. The highest amount of information displayed in the experiments did not overload the subjects who received the information in monochrome-green graphic form. The conclusion is that the means of representing information is significant and leads to a higher or lower information overload threshold depending on the method chosen.

C. RECOMMENDATIONS FOR FUTURE STUDY

1. Determine Monochrome Threshold Region

There was no information overload in the monochrome phase of the graphics experiment. A follow-on study to bound the threshold region for information overload using a variation of chess could be conducted.

2. Determine Information Overload Region

This study did not find an optimal amount of information. A study to determine the threshold regions could be conducted.

3. <u>Increase Tasks</u>

Additional experimentation with more difficult information processing tasks could be conducted. Maybe this experiment did not challenge the abilities of the players enough.

4. <u>Vary Decision Time</u>

Replicate experiments and allow one and four minutes for a subject to make a move. The object would be to determine if a decrease or increase in time would affect the MOE.

APPENDIX A

TABLES

TABLE III-1

COLOR EXPERIMENT DATA SHEET

TRIAL 1

SUBJECT	SKILL LEVEL	INTELLIGENCE LEVEL	SCENARIO	SCORE
1	2	3	1	-2274
2	2	2	1	-32753*
3	2	1	1	-4115
4	2	4	1	-4075
5	2	3	1	-2436
6	1	2	1	-6134
7	1	1	2	-2379
8	2	4	2	-1181
9	2	3	2	-690
10	2	2	2	-1937
11	2	1	2	-2067
12	3	4	2	-872
13	2	3	3	-1537
14	2	2	3	-1488
15	2	1	3	-4558
16	2	4	3	-1558
17	2	3	3	-619
18	1	2	3	-3503
19	1	1	4	-4295
20	2	4	4	-1110
21	2	3	4	-1798
22	2	2	4	-3811
23	2	1	4	-32753*
24	2	4	4	-799
25	2	3	1	-414
26	2	3	4	-3555

TABLE III-1 [CONTINUED]

TRIAL 2

SUBJECT	SKILL LEVEL	INTELLIGENCE LEVEL	SCENARIO	SCORE
1	2	2	2	-2067
2	2	3	2	-1404
3	2	3	3	-2884
4	2	3	3	-640
5	2	2	4	-2158
6	1	3	4	-1548
7	1	3	1	-1679
8	2	3	1	-1713
9	2	1	3	-4467
10	2	1	3	-2886
11	2	2	4	-937
12	3	2	4	-1123
13	2	1	1	-901
14	2	1	1	-1929
15	2	2	2	-3141
16	2	2	2	-532
17	2	4	4	-630
18	1	4	4	-5069
19	1	4	1	-1587
20	2	1	1	-2680
21	2	4	2	-861
22	2	4	2	-782
23	2	4	3	-6482
24	2	1	3	-32753*
25	2	2	2	-2074
26	2	2	2	-2612

TABLE III-1 [CONTINUED]

TRIAL 3

SUBJECT	SKILL LEVEL	INTELLIGENCE LEVEL	SCENARIO	SCORE
1	2	1	3	-7286
2	2	1	4	-2740
3	2	2	2	-1982
4	2	2	4	-3579
5	2	4	2	-2037
6	1	4	3	-5597
7	1	4	3	-4413
8	2	1	4	-3290
9	2	2	1	-761
10	2	3	4	-2495
11	2	3	1	-4409
12	3	3	3	-4540
13	2	4	2	+650
14	2	4	4	-1235
15	2	4	1	-431
16	2	1	4	-1561
17	2	2	1	-1148
18	1	3	2	-3145
19	1	3	2	-4381
20	2	3	3	-2784
21	2	1	1	-1203
22	2	1	3	-3537
23	2	2	1	-1872
24	2	2	2	-2076
25	2	1	3	-3532
26	2	1	1	-3356

TABLE III-1 [CONTINUED]

TRIAL 4

SUBJECT	SKILL LEVEL	INTELLIGENCE LEVEL	SCENARIO	SCORE
1	2	4	4	-1534
2	2	4	3	-2559
3	2	4	4	-1664
4	2	1	2	-2966
5	2	1	3	-32753*
6	1	1	2	-32753*
7	1	2	4	-1571
8	2	2	3	-2942
9	2	4	4	-3549
10	2	4	1	-1563
11	2	4	3	-2238
12	3	1	1	-3794
13	2	2	4	-55
14	2	3	2	-2157
15	2	3	4	-969
16	2	3	1	-947
17	2	1	2	-2546
18	1	1	1	-4226
19	1	2	3	-4834
20	2	2	2	-1976
21	2	2	3	-3476
22	2	3	1	-2352
23	2	3	2	-2608
24	2	3	1	-1713
25	2	4	4	-1654
26	2	4	3	-5176

TABLE III-2

MONOCHROME EXPERIMENT DATA SHEET

TRIAL 1

SUBJECT	SKILL LEVEL	INTELLIGENCE LEVEL	SCENARIO	SCORE
1	2	3	1	-2796
2	1	2	1	-32753*
3	2	1	1	-1803
4	2	4	1	-2553
5	2	3	1	-1995
6	1	2	1	-4212
7	2	1	2	-2333
8	2	4	2	-1300
9	3	3	2	-1507
10	2	2	2	-2888
11	2	1	2	-3236
12	3	4	2	-1521
13	2	3	3	-997
14	1	2	3	-2032
15	1	1	3	-6760
16	2	4	3	-1800
17	2	3	3	-436
18	2	2	3	-5679
19	2	1	4	-2286
20	2	4	4	-1460
21	3	3	4	-367
22	2	2	4	-2742
23	2	1	4	-4165
24	2	4	4	-1765
25	2	3	1	-3081
26	2	3	4	-2990

TABLE III-2 [CONTINUED]

TRIAL 2

SUBJECT	SKILL LEVEL	INTELLIGENCE LEVEL	SCENARIO	SCORE
1	2	2	2	-2490
2	1	3	2	-3346
3	2	3	3	-2627
4	2	3	3	-964
5	2	2	4	-1483
6	1	3	4	-3638
7	2	3	1	-1463
8	2	3	1	-1377
9	3	1	3	-1109
10	2	1	3	-4809
11	2	2	4	-4229
12	3	2	4	-864
13	2	1	1	-3884
14	1	1	1	-2414
15	1	2	2	-3121
16	2	2	2	+287
17	2	4	4	-564
18	2	4	4	-2158
19	2	4	1	-2900
20	2	1	1	-3384
21	3	4	2	-265
22	2	4	2	-4184
23	2	4	3	-1232
24	2	1	3	-32753*
25	2	2	2	-3190
26	2	2	2	-458

TABLE III-2 [CONTINUED]

TRIAL 3

SUBJECT	SKILL LEVEL	INTELLIGENCE LEVEL	SCENARIO	SCORE
1	2	1	3	-1093
2	1	1	4	-4675
3	2	2	2	-1839
4	2	2	4	-1962
5	2	4	2	-2096
6	1	4	3	-1930
7	2	4	3	-644
8	2	1	4	-2469
9	3	2	1	-775
10	2	3	4	-182
11	2	3	1	-3357
12	3	3	3	-3594
13	2	4	2	-893
14	1	4	4	-2002
15	1	4	1	-32753*
16	2	1	4	-2379
17	2	2	1	-1657
18	2	3	2	-382
19	2	3	2	-3065
20	2	3	3	-3762
21	3	1	1	-67
22	2	1	3	-5007
23	2	2	1	-229
24	2	2	2	-2968
25	2	1	3	-1963
26	2	1	1	-3464

TABLE III-2 [CONTINUED]

TRIAL 4

SUBJECT	SKILL LEVEL	INTELLIGENCE LEVEL	SCENARIO	SCORE
1	2	4	4	-1120
2	1	4	3	-32753*
3	2	4	4	-1489
4	2	1	2	-5674
5	2	1	3	-2932
6	1	1	2	-3889
7	2	2	4	-2603
8	2	2	3	-4061
9	3	4	4	-489
10	2	4	1	-1548
11	2	4	3	-1816
12	3	1	1	-2434
13	2	2	4	-1530
14	1	3	2	-1645
15	1	3	4	-32753*
16	2	3	1	-1466
17	2	1	2	-1883
18	2	1	1	-4168
19	2	2	3	-4577
20	2	2	2	-2296
21	3	2	3	-1353
22	2	3	1	-695
23	2	3	2	-2246
24	2	3	1	-2692
25	2	4	4	-413
26	2	4	3	-2004

TABLE III-3

ALPHANUMERIC EXPERIMENT DATA SHEET

TRIAL 1

SUBJECT	SKILL LEVEL	INTELLIGENCE LEVEL	SCENARIO	SCORE
1	2	3	1	-3237
2	1	2	1	-1155
3	2	1	1	-1477
4	2	4	1	-1834
5	2	3	1	-302
6	2	2	1	-319
7	2	1	2	-2181
8	2	4	2	-2317
9	3	3	2	-2041
10	2	2	2	-5722
11	2	1	2	-1901
12	2	4	2	-2915
13	2	3	3	-5558
14	2	2	3	-5968
15	2	1	3	-2896
16	2	4	3	-6812
17	2	3	3	-3351
18	1	2	3	-6207
19	2	1	4	-2599
20	3	4	4	-2308
21	2	3	4	-1481
22	2	2	4	-3058
23	2	1	4	-1000
24	2	4	4	-2770
25	2	3	1	-682
26	2	2	1	-2319
27	1	1	1	-1907
28	2	4	1	-2907
29	2	3	1	-1408
30	3	2	1	-2643
31	2	1	2	-4320

TABLE III-3 [CONTINUED]

TRIAL 2

SUBJECT	SKILL LEVEL	INTELLIGENCE LEVEL	SCENARIO	SCORE
1	2	2	2	-3963
2	1	3	2	-3480
3	2	3	3	-3337
4	2	3	3	-2711
5	2	2	4	-2473
6	2	3	4	-3026
7	2	3	1	-1263
8	2	3	1	-1618
9	3	1	3	-1545
10	2	1	3	-3731
11	2	2	4	-1309
12	2	2	4	-2303
13	2	1	1	-2573
14	2	1	1	-32753*
15	2	2	2	-1494
16	2	2	2	-593
17	2	4	4	-936
18	1	4	4	-2426
19	2	4	1	-3340
20	3	1	1	-1731
21	2	4	2	-1717
22	2	4	2	-1224
23	2	4	3	-4740
24	2	1	3	-3041
25	2	2	2	-2360
26	2	3	2	-4076
27	1	3	3	-2861
28	2	3	3	-859
29	2	2	4	-2219
30	3	3	4	-1033
31	2	3	1	-1887

TABLE III-3 [CONTINUED]

TRIAL 3

SUBJECT	SKILL LEVEL	INTELLIGENCE LEVEL	SCENARIO	SCORE
1	2	1	3	-6247
2	1	1	4	-32753*
3	2	2	2	-335
4	2	2	4	-1525
5	2	4	2	-3091
6	2	4	3	-2525
7	2	4	3	-1843
8	2	1	4	-3093
9	3	2	1	-334
10	2	3	4	-888
11	2	3	1	-2698
12	2	3	3	-2382
13	2	4	2	-1472
14	2	4	4	-1000
15	2	4	1	-489
16	2	1	4	-1904
17	2	2	1	-1947
18	1	3	2	-2995
19	2	3	2	-1654
20	3	3	3	-3844
21	2	1	1	-7151
22	2	1	3	-32753*
23	2	2	1	-1494
24	2	2	2	-1244
25	2	1	3	-1572
26	2	1	4	-2486
27	1	2	2	-2508
28	2	2	4	-2776
29	2	4	2	-2429
30	3	4	3	-4494
31	2	4	3	-3754

TABLE III-3 [CONTINUED]

TRIAL 4

SUBJECT	SKILL LEVEL	INTELLIGENCE LEVEL	SCENARIO	SCORE
1	2	4	4	-1950
2	1	4	3	-32753*
3	2	4	4	-2395
4	2	1	2	-3808
5	2	1	3	-5058
6	2	1	2	-5463
7	2	2	4	-32753*
8	2	2	3	-30300
9	3	4	4	-1014
10	2	4	1	-3339
11	2	4	3	-947
12	2	1	1	-2897
13	2	2	4	-1006
14	2	3	2	-1621
15	2	3	4	-989
16	2	3	1	-2306
17	2	1	2	-3052
18	1	1	1	-652
19	2	2	3	-5307
20	3	2	2	-1356
21	2	2	3	-881
22	2	3	1	-1731
23	2	3	2	-1694
24	2	3	1	-1413
25	2	4	4	-1201
26	2	4	3	-3988
27	1	4	4	-1660
28	2	1	2	-5882
29	2	1	3	-2717
30	3	1	2	-1371
31	2	2	4	-1586

* Score reflecting checkmate or checkmate imminent.

APPENDIX B

EXPERIMENT HANDOUT

SIMULATION EXPERIMENT: GRAPHICS WARGAME USING CHESS MOVES

PLAYER INSTRUCTIONS

PURPOSE

This is a thesis experiment. The experiment is being conducted during OS4602. This is an experiment in the value of military intelligence (information) correlated to the way the information is presented.

OVERVIEW

All OS4602 students and a few additional individuals will participate in this experiment. As a participant, you will provide approximately three one hour periods of your time. At the end of the third hour, you will have played four simulated battlefield scenarios. The four games will be completed by the end of the fall quarter of FY85, course OS4602.

The battlefield situations are presented on the WAR Lab RAMTEK monitors using a graphics display chess board and appropriate chess pieces. The game of chess is the medium and the chess pieces are the forces employed. The chess board is the general battlefield. Think of the various chess pieces as maneuver elements. The rules of chess describe these maneuver elements, and the capabilities of each of the maneuver elements. To help you, the rules of chess are attached.

This experiment is not to evaluate your chess skills per se. A level of intelligence information showing which enemy elements can be attacked and/or which friendly elements are vulnerable to or safe from attack is provided, or is missing, with each battlefield situation.

You are to conduct your campaign one offensive or defensive move at a time. After your first move, each subsequent move must be accomplished within two minutes after the challenger (a computerized chess game) makes its move.

There are 52 participants and one designated area in the WAR Lab for conducting the experiment. Therefore, blocks of

time for Lab usage will be scheduled. Enter your name in three non-contiguous blocks on the WAR Lab usage board (IN-157).

THE EXPERIMENT

In order to participate fully in this experiment, you should know the rules of chess (see the attached sheet synopsis). In most scenarios, "intelligence" information will be given to facilitate your play (moves).

The display is like the one on the attached rules sheet. Moves are made by placing the tablet cursor on the chess piece you want to move, indicating your choice to the computer by pushing a button on the mouse, moving the tablet cursor to the square you want to move to and then indicating this to the computer by pushing a button on the mouse again. If the move is illegal, the computer will tell you and you'll have to try again.

TO PLAY THE GAME

NOTE: The following LOGON, RUN, and monitor selection commands shown below are for your information. The umpire will usually accomplish these actions for you.

Turn on the appropriate RAMTEK monitor and terminal.

*****ENGAGE THE TERMINAL CAPS LOCK KEY*****

Log on a designated WAR Lab VAX VT100/102.

```
     User_name:      CHESS <CR>
     Password:
```

At the prompt ($) enter: SD฿.GRAPHICS<CR>

Next, enter: RUN฿MYPLAY <CR>

After conferring with the umpire, select the appropriate monitor (1, 2, or 3) for your game display.

*****FROM THIS POINT ON, YOU WILL BE PROMPTED FOR INPUT*****

The umpire will provide a briefing at the beginning of each game.
After the umpire initializes his terminal, you will be prompted for your last name. This is only used for experiment evaluation identification and will not be disseminated.

Next, you will be asked your experience level. Please respond the same for each of your scenarios.

When your board display appears, push the reset button on your mouse tablet so your cursor will appear if it doesn't appear immediately.

Your first move is not timed so you may somewhat leisurely study the "situation" before commencing your campaign.

Note: All initial set-ups are approximately ten moves into a game, the sides are equal in strength, and it is your move.

APPENDIX C

UMPIRE INSTRUCTIONS

SIMULATION EXPERIMENT: GRAPHICS WARGAME USING CHESS MOVES

UMPIRE INSTRUCTIONS

BRIEFING

After the game scenario is set up for both the player and the umpire, brief the player as follows:

1. The participant will play four games in Color or in Monochrome as indicated on the master schedule.

For two of the games, you will see all the chess pieces. Of these two games, one will depict safe areas for your pieces and denote enemy pieces you can capture on your next move.

For two of the games, you will see all your pieces and only those enemy pieces you can capture on your next move. Of these two games, one will depict safe areas for your pieces.

Safe areas are depicted by a small square in the lower left corner of a chessboard square.

A small square in the lower right corner of a chessboard square denotes an enemy piece you could capture on your next move.

2. The games will not necessarily be played to their conclusion.

3. Caution the player that this is a war game and if the player inadvertently moves to a square already occupied by a friendly piece, it can be considered a legal move by the computer. This means the player may capture his or her own piece. (This will probably only happen when Monochrome is being used and the player forgets which pieces are friendly forces.)

4. Describe each of the pieces and their appropriate moves as required.

5. Explain that a move is final and cannot be recalled after completion. If the player desires to move a piece other than the one initially identified to the computer, the player can give the chosen piece an illegal move to cancel the order.

6. Show how moves are made with the cursor and explain the the use of the menu to castle on the king or queen side.

7. En Passant, an unusual way for one pawn to capture another pawn, is not allowed by the computer chess program. An En Passant capture is defined as follows:

A pawn attacking a square crossed by an enemy pawn which has been advanced two squares on its initial move, may capture, but only in the move immediately following the enemy pawn's initial move. This is as if the enemy pawn had only advanced one square on its initial move. From a military standpoint, it is as if the enemy "crossed" a field of fire giving you the option of declaring capture or not.

8. If there are no questions from the player, the first game is ready to begin.

9. After the first game, display the graphics prior to set up of the Chess Challenger to give the player more time to study the board prior to the initial move.

10. After the last game, at the player's terminal, enter Control C <CR>, LO <CR>.

11. After the last game, at the umpire's terminal, enter Control C <CR>.

```
DIR<CR>  (to check FOR008.DAT;* files)
SD.<CR>  (to return to CHESS)
COPY [.GRAPHICS]FOR008.DAT;* [.FILE]?? (if color)
                             [.GAME]?? (if monochrome)
SD.<CR>
SD.GRAPHICS<CR>
DIR<CR>
DELETE FOR008.DAT;*
LO<CR>
```

COMPUTER GAME SCENARIO

Using the master player scenario list:

1. Determine if the player gets Color or Monochrome displays and set-up the player RAMTEK appropriately. To give a monochrome display, disconnect the top (blue) and

bottom (red) color cables, leaving monochrome green. NOTE: Don't forget to reconnect the cables after the games are played. Normal chess white pieces are BLUE and normal chess black pieces are RED because the normal chessboard is black and white in these graphics games.

2. Determine which board set-up the player will receive and set-up the Chess Challenger board accordingly.

3. Determine which intelligence level to present to the player.

4. Turn the player's RAMTEK and terminal on.

5. With the caps key "on", log player on the system as follows:

```
CHESS<CR>
(PASSWORD)<CR>
SDø.GRAPHICS<CR>
RUNøMYPLAY<CR>
(input player monitor number)<CR>
(player enters his or her last name)<CR>
(player enters his or her skill level)<CR>
```

The player will have a reasonable amount of time to study the initial board set-up with no penalty prior to the first move. After the first move, each subsequent player move must be accomplished within 2 minutes or the player will incur a penalty.)

6. Turn the umpire's RAMTEK and terminal on.

7. With the caps key "on", log yourself on the system as follows:

```
CHESS<CR>
(PASSWORD)<CR>
SDø.GRAPHICS<CR>
RUNøMYUMP<CR>
(input the umpire monitor number)<CR>
(select intelligence level 1, 3, 5, or 6)<CR>
YES<CR>
Y<CR>
(select canned scenario A, B, C, or D)<CR>
Y<CR> if the set-up shown is correct or N<CR> if not.
```

CHESS CHALLENGER OPERATIONS

After appropriately setting up the Chess Challenger playing surface, plug the unit in and give the following sequence of commands:

RE D8 CL
RE D7 CL
(NOTE: Flashing light for BLACK and solid on light for WHITE)
KING
QUEEN
ROOK
BISHOP
KNIGHT
PAWN
(Recheck piece settings)
CL
RE E1 E3 CL

It is now the player's move. The Chess Challenger will produce a "score" if prompted prior to your making BLACK's move. If a score is required:

1. Make BLACK's move on the tablet.

2. Press ST on the Chess Challenger for a four-digit hexadecimal code.

Example:

4A F3 = BL advantage

4A.F3 = WH advantage

3. Enter the code and advantage with the terminal keyboard.

4. Then, make BLACK's move on the Chess Challenger.

CORRECTION ROUTINE

If the program blows:

1. Copy the error message in total.

2. Control C both terminals.

After $ prompt, type:

3. SD.<CR> (takes you back to CHESS)

Look for highest number in file FOR008.DAT;*.

4. SD␢.THESIS<CR>

5. DIR<CR> (to find FOR008.DAT;* files)

6. PRINT<CR>

7. PRINT␢FOR008.DAT;(number seen in directory)/QUEUE=LPA0

Retrieve printout and try to run another scenario if possible.

APPENDIX D

QUESTIONNAIRE

Chess Experiment Questionnaire

Now that you have played your four chess war games, complete this questionnaire and return it to the experiment umpire.

Purpose:

This questionnaire will assist in quantitative evaluation of the Chess Experiment.

Participant's name:___________________________

Overview:

You played four chess war game scenarios. Your displays were in color, with friendly forces in blue and enemy forces in red, or the displays were monochrome green, with no apparent differentiation between friendly and enemy forces. You began your play after approximately ten moves had been made. The chessboard strengths for each side were about equal. For some of the scenarios, additional information was provided. Also, "perishable", partially coded information was available because the chess set the umpire used announced each of its moves, using its voice synthesizer, and stated the types of pieces involved.

Chess Experiment:

Two of the scenarios displayed all the chessboard pieces.

One of those two games identified your safe moves by placing a small square in the lower left corner of the "safe" squares. This same scenario identified enemy pieces which could be attacked by placing a small square in the lower right corner of appropriate squares. Indicate below the extent of your usage of this additional information:

Use of additional information:
(place an "X" as appropriate)

( ) not at all

( ) for a few of my moves

( ) for about half of my moves

( ) for most of my moves

( ) for all my moves

Briefly state your rationale for use or non-use of the additional information provided:

Rate your aggressiveness in playing that game using the following scale:

1 = very defensive, non-aggressive play
2 = somewhat defensive play
3 = neutral, neither defensive nor offensive
4 = somewhat offensive play
5 = very offensive, aggressive play

<u>At beginning of game</u>	<u>Toward end of game</u>
( )	( )

The other game provided no additional information.

Rate your aggressiveness in playing that game using the following scale:

1 = very defensive, non-aggressive play
2 = somewhat defensive play
3 = neutral, neither defensive nor offensive
4 = somewhat offensive play
5 = very offensive, aggressive play

<u>At beginning of game</u>	<u>Toward end of game</u>
( )	( )

Two of the scenarios displayed your chess pieces and only those enemy pieces which could be attacked.

One of those two games identified your safe moves by placing a small square in the lower left corner of the "safe squares. Indicate below the extent of your usage of this additional information:

Use of additional information:
(place an "X" as appropriate)

( ) not at all

( ) for a few of my moves

( ) for about half of my moves

( ) for most of my moves

( ) for all my moves

Briefly state your rationale for use or non-use of the additional information provided:

Rate your aggressiveness in playing that game using the following scale:

1 = very defensive, non-aggressive play
2 = somewhat defensive play
3 = neutral, neither defensive nor offensive
4 = somewhat offensive play
5 = very offensive, aggressive play

At beginning of game	Toward end of game
( )	( )

The other game provided no additional information.

Rate your aggressiveness in playing that game using the following scale:

1 = very defensive, non-aggressive play
2 = somewhat defensive play
3 = neutral, neither defensive nor offensive

4 = somewhat offensive play
5 = very offensive, aggressive play

At beginning of game	Toward end of game
( )	( )

Provide any additional comments concerning the Chess Experiment:

LIST OF REFERENCES

1. Miller, G. A., "The Magical Number Seven, Plus or Minus Two: Some Limits on Our Capacity for Processing Information," The Psychological Review, v. 63, no. 2, pp. 81-97, March 1956.

2. Purdue University Report 15, The Effect of Information Quantity and Time Spent in Military Decision Making on the Degree of Risk Taking: An Analysis Via an Experimental Simulation Technique, by S. Streufert and S. C. Streufert, Purdue University, West Lafayette, Indiana, September 1968.

3. Air Force Operational Applications Laboratory Report ESD-TDR-62-48, Human Data Processing Limits in Decision Making, by J. R. Hayes, July 1962.

4. Army Personnel Research Office TRN 178, Decision Making with Updated Graphic vs Alpha-numeric Information, by F. L. Vincino and S. Ringel, November 1966.

5. O'Bryant, K. M. and Risney, R. G., An Experiment in the Value of Military Intelligence, Master's Thesis, Naval Postgraduate School, Monterey, California, 1984.

6. Joint Chiefs of Staff, Joint War Games Agency, JWGA-500-66, Joint War Gaming Manual, pp. 48-54, 1 December 1966.

7. Harkness, K., The Official Blue Book and Encyclopedia of Chess, p. 344, David McKay Company, Incorporated, 1956.

8. Fidelity Electronics, Ltd., Miami Document 513-1086B02, Owner's Manual for Super Sensory Nine.

BIBLIOGRAPHY

Barton, R. F., A Primer on Simulation and Gaming, Prentice-Hall, 1970.

Hicks, C. R., Fundamental Concepts in the Design of Experiments, 2nd ed., Holt, Rinehart and Winston, 1973.

Hwang, J., and others, ed. Selected Analytical Concepts in Command and Control, Gordon and Breach, 1982.

Kempthorne, O., The Design and Analysis of Experiments, Krieger, 1973.

Machol, R. E., ed. Information and Decision Processes, McGraw-Hill, 1960.

Martin, F. F., Computer Modeling and Simulation, Wiley, 1968.

Miller, J. G., Living Systems, McGraw-Hill, 1978.

Naval Postgraduate School Technical Report NPS-55-78-032, Experimentation Manual. Part I: Experimentation Methodology, by D. R. Barr, G. K. Poock, and F. R. Richards, Naval Postgraduate School, Monterey, California, 1978.

Puscheck, H. C., The Development and Application of a Simple Wargame to the Study of Sequential Decision Making in a Conflict Environment, Ph.D. Thesis, Purdue University, West Lafayette, Indiana, 1969.

Shelly, M. W.,II, ed. Human Judgments and Optimality, Wiley, 1964.

Walker, H. M. and Lev, J., Statistical Inference, Holt, Rinehart and Winston, 1953.

Wonnacott, T. H. and Wonnacott, R. J., Introductory Statistics, 3rd ed., Wiley, 1977.

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